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IN THIS ISSUE

How well do industrial wage earners in the United States eat? This question quite properly is of considerable concern to those who believe that it is now more important than ever to put into effect all our knowledge of preventive measures in order to maintain the health of the civilian workers essential to the war effort.

To obtain further information on food habits of workers, an investigation was made of the diets of more than 1,000 employes in an aircraft plant. The Study was sponsored by the Committee on Nutrition in Industry of the National Research Council, and findings are reported in an article entitled "Diets of a Group of Aircraft Workers in Southern California" by Dorothy G. Wiehl. Very few of the men in the Study were eating a diet which would fully meet dietary standards recommended by nutrition authorities. The choice of vegetables resulted in too few of the green and yellow varieties which are needed for vitamins, citrus fruits were eaten infrequently, and too little milk was consumed. It is again shown that a diet which satisfies the appetite may fall short of providing the essential nutrients which are required to maintain good nutritional status.

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Despite the marked advances in public education in this country during the past fifty years, we have had no adequate data concerning the actual school attainment of our total population. For some decades prior to 1940 the Federal censuses inquired only into the ability of a person to read and write, so the two-fold classification illiterate-literate constituted the sum of official data on this subject. A valuable innovation of the 1940 Census was the inclusion of a question concerning actual number of years of school completed. Dr. Henry S. Shryock of the Bureau of the Census has prepared for this issue a paper "1940 Census Data on Number of Years of School Completed." It is based upon tabulations

available to date for the total population 25 years of age and over, broken down by urban-rural status, nativity and color, sex, and place of residence. Data such as these are of value from many points of view. They are essential to an adequate understanding of the functioning of our people as workers, consumers, and voting citizens.

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In the report "The Experimental Error of Determinations of Ascorbic Acid in Plasma by Micromethod of Mindlin and Butler" by Gilbert W. Beebe, the accuracy of ascorbic acid determinations by the micromethod is compared with the macromethod. This paper from the series in Medical Evaluation of Nutritional Status discusses the procedural conditions under which the minimum error for the micromethod was obtained and shows that the sacrifice of accuracy which the method entails is slight in view of its economical blood requirements.

DIETS OF A GROUP OF AIRCRAFT WORKERS IN SOUTHERN CALIFORNIA[1]

DOROTHY G. WIEHL

THE importance of developing measures to improve the diets of industrial workers has been discussed in a previous report (1) from the Committee on Nutrition in Industry of the National Research Council. A general survey of plant facilities for meals, of food habits of workers, and of evidence on dietary deficiencies among industrial employes led the Committee to the conclusions that more detailed investigations of the problem were greatly needed and that the present situation requires prompt, remedial measures to promote better dietary practices. There is much evidence from research on nutrition that workers who are well fed and have neither hunger nor "hidden hunger" may be expected to have better health, greater efficiency, and higher morale.

In order to obtain more definite data on the dietary deficiencies of industrial workers and their relation to health and absenteeism, an intensive study was planned and sponsored by the Committee on Nutrition in Industry. This investigation was begun at the Lockheed Aircraft Corporation, Burbank, California, in November, 1941, and included: (1) the collection of dietary histories; (2) medical examinations to determine the prevalence of various specific nutritional diseases; (3) a follow-up study of absences and accidents over a period of one year. The investigation is still in progress and the present report relates only to an analysis of the diet histories.

[1] This survey of diets is part of an investigation of the nutritional status of employes in a war industry. The study is sponsored jointly by the Los Angeles County Committee on Nutrition in Industry and the Committee on Nutrition in Industry of the National Research Council. The County of Los Angeles, the California Institute of Technology, and the Lockheed Aircraft Corporation cooperated in the study and assistance has been afforded by the California Fruit Growers Association.

The investigation is being directed by Dr. H. Borsook, California Institute of Technology. The collection of the data on diets was organized by the author of this report, and the analysis was carried out by the Milbank Memorial Fund. Views expressed in this report are solely those of the author.

Family diets and those of children have been studied extensively, but little attention has been given to the diets of individual workers. In general, it may be inferred that if the family diet is poor it is unlikely that some members of the family will have a completely adequate diet. However, there is evidence from data on family diets and on food consumption of individual members of the family collected in several Canadian studies (2) that the wage earner may consume more than a proportionate share of at least some of the available foods. Thus, in satisfying his natural desire for calories, the worker may obtain a more adequate supply of some essential nutrients than is obtained by women and children in the family. But in the Canadian studies, the diets of the men were more often deficient in vitamin A and vitamin C than those of the children, although they were less likely to be deficient in protein, iron, and vitamin B_1. Many studies of diets of wage-earners' families in the United States have shown that only a small percentage of families has a food supply which furnishes amounts of the principal essential food elements which are equal to the safe allowances recommended by nutrition authorities.

This study of the diets of about 1,100 aircraft workers was designed to fill in some of the gaps in our knowledge of what are the principal dietary deficiencies of industrial workers, and to describe the food choices and food failures which lead to these deficiencies. Such information can serve as an important guide in planning measures to improve dietary conditions. As the study was made in the winter months, the diets may have been somewhat worse than they would have been in late spring or summer. However, consumption of the right foods is necessary at all seasons. The diets of workers in California probably are not typical in all respects of those of workers in other regions. Dietary differences from region to region affect chiefly the relative prevalence of deficiencies of the various nutrients. In the study of diets of families by Stiebeling and Phipard (3), 14 per cent of the diets of families in the Pacific coast

states, chiefly California, were graded as good, and for three other regions the percentages ranged from 11 to 21. However, the percentage of poor diets was lowest for Pacific coast families, 40 per cent as against 46 to 60 per cent in other sections of the country; and the percentage of fair diets was highest for Pacific coast families, 46 per cent compared with 28 to 33 per cent. Thus, this family study found the diets to be slightly better in California, but the majority was definitely in need of improvement.

The Sample

The men from whom diet histories were obtained had volunteered to participate in the special study of nutritional status. Diet records from office and clerical personnel have not been included. All were on the evening or "swing" shift at the time the record was taken, with the exception of about fifty men whose employment began after the record was taken.

Ages of the men in the Study are shown in Table 1. The majority was young with nearly three-fourths of the group under 30 years of age, and 46 per cent under 25 years of age. Only nine of the

Table 1. Age distribution of aircraft workers in nutrition study in California, November 1941-February 1942.

Age Group	Number of Men	Per Cent of Total	Cumulated Per Cent
Total, Age Known	1,080	100.0	
Under 20 Years	79	7.3	7.3
20–24 Years	415	38.4	45.7
25–29 Years	299	27.7	73.4
30–34 Years	156	14.4	87.9
35–39 Years	64	5.9	93.8
40–44 Years	38	3.5	97.3
45–49 Years	20	1.9	99.2
50–54 Years	8	0.7	99.9
55–59 Years	1	0.1	100.0
Unknown Age	23		

Period of Time	Time in California		Duration of Employment	
	Number of Men	Per Cent of Total	Number of Men	Per Cent of Total
Total Known Period	1,073	100.0	1,100	100.0
Pre-employment	—	—	49	4.5
Less Than 3 Months	38	3.5	33	3.0
3 to 11 Months	302	28.1	595	54.1
1 Year, Less Than 2 Years	139	13.0	285	25.9
2 Years, Less Than 3 Years	65	6.1	66	6.0
3 Years, Less Than 5	88	8.2	59	5.4
5 Years, Less Than 10	116	10.8	13	1.2
10 Years or Longer	325	30.3	—	—

Table 2. Duration of residence in California and of employment at this aircraft plant of employes in nutrition study, November 1941-February 1942.

1,080 men were between 50 and 60 years of age, and twenty were from 45 to 49 years old.

The period of employment at this factory had been less than one year for 62 per cent of the group; but only 7.5 per cent had been employed less than three months. About one in eight of the men had been employed two years or longer.

Nearly one-third of the men had lived in California less than one year, and 45 per cent had been in California less than two years. On the other hand, 30 per cent had lived in California ten years or longer. More detailed distributions of the duration of employment and time lived in California are shown in Table 2.

Slightly less than one-half, 44 per cent, of these men were single, 54 per cent were married, and 1.5 per cent had been married but were widowed or divorced.

Inquiry was made as to whether meals were eaten in a restaurant, a boarding house, or "at home." About three-fourths of the men ate meals "at home," 15 per cent ate in restaurants most of the time, and 10 per cent ate at a boarding house. The "at home" group includes those who lived with families, whether or not related, and also includes a few men who joined together and "kept house" for themselves.

Description of Diet Histories

Information concerning diets of the employes was obtained by interview and was of two types. One record was a quantitative estimate by the informant of all food consumed during the two days preceding the interview; the other record was for the remaining five days of a one-week period and required, for the most part, only the listing of foods in selected categories which had been included in the diet.

The two-day quantitative diet history furnished a complete description of all food consumed at each meal and between meals. Quantities were stated, when possible, in ordinary units, such as, a glass of milk, two slices of bread, one pat of butter, one medium-sized potato, two chops, etc. For many foods, estimates of the size of the serving had to be made and to assist the informant in describing the servings, models of measured quantities of several foods were displayed on the interviewer's desk, and glasses of three different sizes were also at hand. These were used as standards of reference and the employe was asked to estimate the amounts of different foods consumed in relation to some one of the sample portions. Although the quantitative values for each food obtained by this method are only approximate, it is believed that the estimate of total food intake is reasonably accurate and provides a satisfactory basis for classifying diets into several broad groups according to consumption levels.

The five-day report on the use of selected foods was designed to describe qualitative food choices or food habits over a longer period than two days. For each day, the subject was asked to give information on the use of specific foods, as follows:

(1) Number of glasses of milk;
(2) Number of eggs;
(3) Number of slices of whole wheat, or rye bread;
(4) Type of cereal, if any;

(5) Potatoes;
(6) Kinds of vegetables;
(7) Citrus fruits (approximate amounts of juices), and kinds of other fruits;
(8) Kinds of meat.

It is admittedly difficult to remember what one has eaten for a whole week. However, the use of the above food items, in general, represents rather basic food habits, and the errors in reporting seldom would affect a classification of diets with respect to general type or quality.

Method of Analysis. For the two-day quantitative records, estimates were made of the nutritive values of all foods in calories, protein, calcium, iron, vitamin A, thiamin, riboflavin, ascorbic acid, and niacin. For this purpose, extensive tables were prepared[3] from recent publications on food content (4). Vitamin values determined for cooked foods have been used whenever available, and estimates of loss in cooking were made for other cooked foods. Because of the large amount of work and time required for processing the quantitative records, estimates of nutritive values are available at present for only 250 of the dietary histories.

From the five-day qualitative record plus the two-day quantitative record, tabulations of the use during one week of specific foods or types of foods listed above have been made for the entire group. Some explanation of the classification used in making a total count for one week for different food groups is needed. A description of each food group follows:

Milk. A total of the number of glasses of milk reported was

[3] The food value tables were prepared by Mrs. Emily K. Stamm, and her painstaking work is gratefully acknowledged. The nutritive values for several hundred cooked dishes have been calculated from recipes. Allowances made for loss of vitamins in cooking, when assay values on cooked foods were not found, were as follows: ascorbic acid 50 per cent loss; thiamin 40 per cent loss in vegetables and various percentages for meats depending on method of cooking; and riboflavin, various percentages for meats depending on method of cooking, but no estimates of loss in other foods. *See* references 4, a-k. It was assumed that white bread was "enriched," and that rolls, buns, and biscuits were not made from enriched flour.

made; and to this total was added one-half glass of milk for each day on which a breakfast cereal was eaten.

Vegetables. The number of different vegetables reported for any day was the total for that day, as no attempt was made to obtain information as to the number of servings. Vegetables were classified as green or yellow and "other" vegetables. A weekly total was made for each of these two groups of vegetables. Vegetables were classed as green or yellow only when the edible part is colored and vitamin-A content is relatively high. Sweet potatoes were counted as a yellow vegetable, but they were reported very infrequently; and cabbage and lettuce were counted as "other" vegetables. A separate total for tomatoes was made, so that they could be accounted for in a general consideration of the use of vegetables, but also could be combined with citrus fruits. One tomato or a serving of canned tomatoes was counted as one, the tomato in a salad including tomato was counted as one-half; four ounces, or a small glass of tomato juice, was counted as one, and a large glass as two.

Fruit. The number of different fruits eaten each day provided the total for one day and these were summed for the seven days to obtain a total count for fruit for one week. A separate count was made for citrus fruits and "other" fruits. In the citrus fruit count, one orange or one-half grapefruit was one; one tangerine was one-half; and four ounces or a small glass of orange or grapefruit juice counted as one. Fruit salad and fruit pie were counted as one serving of "other" fruit. For raw fruits, as bananas or apples, the number eaten usually was reported and this number was used in the total count for one week.

Eggs. The number of eggs usually was reported and a total count for one week was made. When the number was not stated, but eggs were eaten in some form at any meal, a count of one was used.

Meat, Poultry, Fish. The total count for meat is approximately the number of meals at which a lean meat or fish was eaten. In a

few instances, when the same type of meat was eaten at two meals on the same day, this fact probably was not reported.

Whole Grain Foods. The total number of slices of whole wheat or rye bread eaten in one week was obtained from the number reported for each day. All "dark" bread was counted, although the whole grain content of some of it was limited. Whole grain breakfast cereals were counted as the number of days in the week on which such a cereal was eaten. With a few exceptions, prepared breakfast foods, such as corn flakes and puffed wheat, were not counted.

A. Quality of Diets for One Week

The total use of selected foods or food groups during one week affords a basis for comparing the diets of these employes with the dietary pattern recommended by the National Research Council, Committee on Food and Nutrition (5), for obtaining a safe allowance of protein, minerals, and vitamins.

Before the data on use of different foods are discussed, it will be helpful to consider the significance of the recommended foods with reference to their contribution to a balanced diet with adequate amounts of various essential nutrients. Although some of the essential nutrients are distributed in nature in many different foods, several are present in appreciable amounts in only a few foods. An important example of the latter is ascorbic acid. Citrus fruits and tomatoes are very good sources of this vitamin, and, although a few other foods also are good sources if fresh and raw when eaten, most diets will contain insufficient amounts of ascorbic acid unless a citrus fruit or tomato is included regularly in the diet. The vitamin A allowance of 5,000 International units daily can be obtained from various combinations of foods, nevertheless, a green or yellow vegetable of high vitamin A content is almost a *sine qua non* because it can be replaced satisfactorily only by an exceptionally large consumption of dairy products. The pint of milk daily which

is recommended not only is needed to assure a good source of calcium and to supplement the vitamin A from vegetables, but also is almost indispensable for obtaining the amount of riboflavin which is considered necessary. Meat is the next best source of riboflavin, but some methods of cooking destroy a large percentage of the riboflavin (4k), and only those who eat exceptionally large quantities of meat daily are likely to have an adequate amount of riboflavin unless milk is included in the diet. Niacin (nicotinic acid) must be obtained largely from meat. Thiamin is rather widely distributed in foods, but not in concentrated amounts. Milk, meat, and some vegetables are fairly good sources of thiamin, but there may be considerable loss from cooking; therefore, enriched or whole grain bread, or a whole grain cereal, preferably both, is needed to assure an adequate supply of this vitamin. Eggs are not the most important source of any of the nutrients, but they are a good source of several vitamins as well as of iron and protein. The regular consumption of eggs, therefore, is desirable as a supplement to other foods. Thus, it is apparent that a regular and adequate supply of the principal vitamins and minerals under most circumstances can be obtained best by the consumption each day of a green or yellow vegetable, a citrus fruit or tomato, two glasses of milk or equivalent, an egg, a serving of lean meat, and a whole grain cereal food or enriched bread. Other food combinations can be used to obtain complete nutritional protection, but as a rule, only very specially planned diets furnish all the necessary nutrients when these varieties of foods are not included. The total diet should include some foods not discussed, especially butter or fortified oleomargarine, and potatoes, and an amount of food sufficient to furnish the required energy value.

CONSUMPTION OF SPECIFIC FOODS

The reported frequency within a one-week period with which each of several types of foods was included among the foods chosen,

Table 3. Vegetables and fruits eaten during one week by employes of an aircraft factory in California, November 1941-February 1942.

Number of Times in Week	Vegetables			Fruits		Citrus Fruit and Tomatoes
	Any Kind	Yellow or Green	Tomatoes	Any Kind	Citrus	
	Per Cent of Total					
Total	100.0	100.0	100.0	100.0	100.0	100.0
0	0.7	3.9	48.1	3.4	22.6	11.2
1	1.2	6.5	29.4	2.4	6.5	9.6
2	2.3	13.3	11.0	3.2	10.8	9.4
3	3.3	18.9	5.0	4.0	11.1	10.2
4	5.3	21.7	2.3	4.3	7.4	8.6
5	8.2	14.8	1.3	4.1	8.0	7.2
6	12.6	10.0	1.2	5.9	7.3	7.9
7	15.4	5.7	0.5	8.7	11.3	11.2
8	12.7	2.8	0.6	7.3	3.8	7.3
9	11.2	1.1	0.2	6.5	2.7	4.7
10	8.0	0.5	0.3	6.5	1.5	2.4
11	6.3	0.3	0.1	6.0	1.4	3.0
12	3.8	0.3	0	7.2	1.1	1.1
13	3.2	0	0.1	5.3	0.6	1.1
14	0.8	0	0	5.5	1.4	0.8
15 or More	5.3	0.2	0.2	19.8	2.5	4.5
	Number of Persons Reporting					
Total	1,103	1,103	1,103	1,103	1,103	1,103
0	8	43	530	37	249	123
1	13	72	324	27	72	106
2	25	147	121	35	119	104
3	36	209	55	44	122	112
4	58	239	25	47	82	95
5	90	163	14	45	88	78
6	139	110	13	65	81	87
7	170	63	5	96	125	124
8	140	31	7	80	42	80
9	123	12	2	72	30	52
10	88	6	3	72	16	27
11	69	3	1	66	15	33
12	42	3	0	79	12	12
13	35	0	1	59	7	12
14	9	0	0	61	15	8
15 or More	58	2	2	218	28	50

Table 4. Milk, meat, eggs, and whole grain cereal foods eaten during one week by aircraft employes in California, November 1941-February 1942.

Number Per Week[1]	Milk (Glasses)	Meat		Eggs (Number)	Cereal Products	
		Any Kind	Glandular		"Dark" Bread	Whole Grain Breakfast Food
		Per Cent of Total				
Total	100.0	100.0	100.0	100.0	100.0	100.0
0	11.3	0.5	78.3	18.3	32.9	51.6
1	3.4	0.1	15.4	4.6	20.1	11.0
2	5.7	0.5	4.5	11.2	16.0	7.6
3	5.2	1.2	1.3	6.8	9.5	8.2
4	3.7	2.5	0.2	9.2	6.6	4.0
5	4.2	5.5	0.1	6.7	3.7	5.6
6	3.9	8.5	0.1	7.6	4.3	4.9
7	3.9	16.8	0	9.2	3.4	7.2
8	3.5	24.4	0.1	6.1	1.8	
9	4.4	25.9	0	2.8	0.8	
10	3.6	9.8		2.8	0.5	
11	2.4	2.7		1.5	0.2	
12	3.7	0.8		4.0	0.1	
13	3.8	0.5		1.1		
14	4.5	0.2		5.8		
15+	32.7	0.1		2.3		
		Number of Persons Reporting				
Total	1,103	1,103	1,103	1,103	1,103	1,103
0	125	5	864	203	363	569
1	37	1	170	51	222	121
2	63	5	50	124	177	84
3	57	13	14	75	105	90
4	41	28	2	102	73	44
5	46	61	1	74	41	62
6	43	94	1	84	47	54
7	43	185	0	101	38	79
8	39	269	1	66	20	
9	49	286		31	9	
10	40	108		31	5	
11	26	30		16	2	
12	41	9		44	1	
13	42	6		12		
14	50	2		63		
15+	361	1		25		

[1] Except for "dark" bread, which is the average number of slices per day, as "one or less," "two or more than one," etc.

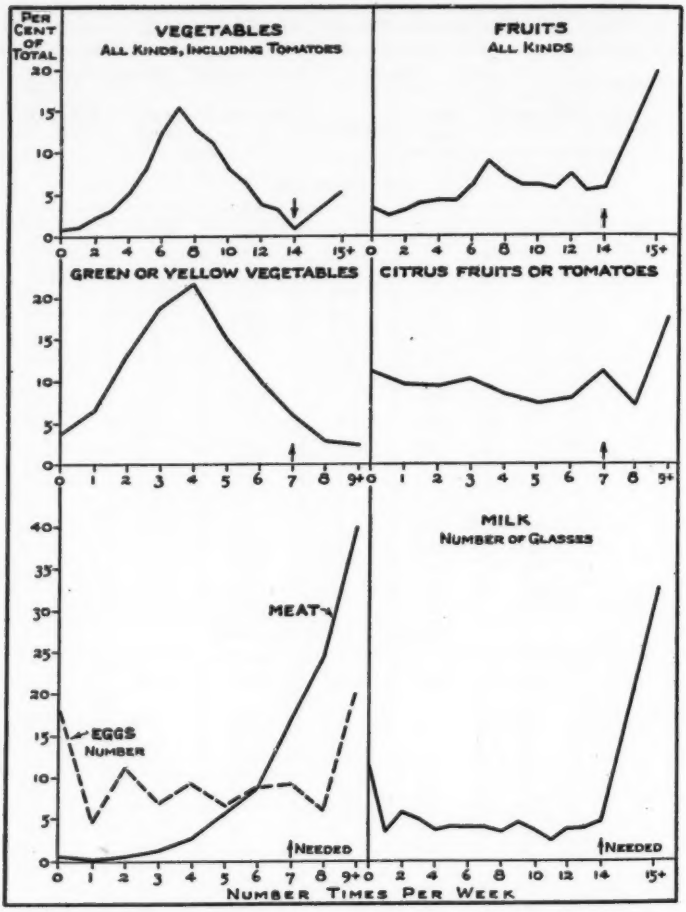

Fig. 1. Percentage distribution of 1,103 diet records for aircraft workers in Southern California according to the reported use of specific foods or food groups during one week.

is shown in Tables 3 and 4, and in Figure 1. The food habits of these employes are shown to differ greatly from the recommended dietary pattern and indicate no appreciation or application of the

principles for obtaining a good diet. A brief comment on the consumption of specific foods follows.

Vegetables. Only 6 per cent of these industrial workers reported that vegetables of any type, including tomatoes, but not Irish potatoes, were eaten as many as fourteen or more times in a week, or an average of at least two per day. One-third of the group had eaten vegetables less than seven times during the week or, on the average, less than one a day.

The choice of green or yellow vegetables was relatively infrequent. Only 11 per cent of the men had had green or yellow vegetables seven or more times during a week, although two-thirds of them had reported seven or more vegetables of some type. A total of three or four green or yellow vegetables occurred most often and 40 per cent of the men reported either three or four. Nearly one-fourth of the men, 24 per cent, had eaten green or yellow vegetables less than three times within the week.

Tomatoes or tomato juice were seldom reported. Nearly one-half of the men reported none during an entire week, and about 30 per cent had had one serving of tomatoes. Although tomatoes are a moderately good source of vitamin A, they are especially significant as a substitute for citrus fruits to furnish ascorbic acid.

Fruits. It is indeed surprising to find that this group in California used very little citrus fruit. About 23 per cent had had none during an entire week, and 17 per cent had had only one or two servings. Only 26 per cent of the men had seven or more servings during a week. If tomato servings during the week are added to those of citrus fruits, only an additional 10 per cent (or a total of 36 per cent) were found to have reported seven or more servings of citrus fruit or tomatoes during the week.

Other fruits were eaten more regularly than the citrus fruits and 73 per cent of the men had had some kind of fruit, including citrus, at least an average of once a day, and about one-fourth of them had had an average of two or more per day.

Milk. The consumption of milk was better than that for either green and yellow vegetables or citrus fruits. Nevertheless, nearly two-thirds of the men (63 per cent) reported less than an average of two glasses per day. About 37 per cent had less than one glass of milk per day, on the average, and 11 per cent had drunk no milk. Somewhat unusual is the finding that 11 per cent of the men drank a quart of milk or more per day.

Eggs. Eggs were not eaten regularly by the majority of the men. Only 35 per cent of them averaged one a day, or seven per week or more, and 34 per cent of the men had two or less eggs within the week.

Meat. Lean meat, fish, or poultry was eaten at least once a day by most of the men. Only 5 per cent of the group had meat less than five times during the week, and four-fifths had meat seven or more times.

Liver and other glandular meat products were reported by only 22 per cent of the men. Fifteen per cent had had one serving within the week, and 5 per cent had had two servings.

Whole Grain Cereal Foods. With the introduction of enriched flour as a substitute for whole wheat breads, consumption of breads or cereals made from the whole grain is more an index of food habits than it is of the probable level of thiamin intake. Most bakeries in this area in California were using enriched flour, but no attempt was made to determine whether the men were eating enriched bread.

One-third of these men ate no whole wheat, rye, or "dark" bread during a week; 20 per cent of them had on the average about one slice per day; and about 20 per cent had four or more slices per day.

Slightly over one-half of the group (52 per cent) used no whole grain breakfast cereal, either prepared or cooked, in a week, and only 7 per cent ate a whole grain cereal every day.

On the charts in Figure 1, an arrow indicates the amount of each food or food group which would correspond to that in the recom-

mended dietary pattern. If the diets had conformed approximately to this pattern, each curve would reach a peak at a point above the arrow. Only the curve for meat consumption is of this type; for other foods, the areas under the curves and to the left of the arrows show that large percentages of the diets were low in their content of yellow or green vegetables, of citrus fruits or tomatoes, of eggs, and of milk. With these dietary deficiencies, the nutritional content would be unsatisfactory in vitamin A, ascorbic acid, riboflavin, thiamin, or calcium, and multiple deficiencies would be expected to occur very frequently.

QUALITATIVE CLASSIFICATION OF DIETS

It is convenient for further discussion of these diets and for summarizing the pattern of individual diets to classify the use of selected foods in a few categories based on the extent of the deviation from amounts recommended in the dietary pattern prepared by the Committee on Food and Nutrition. For five types of food, namely, citrus fruits or tomatoes, green or yellow vegetables, eggs, milk, and meat, the total reported consumption during one week was classified in one of three categories. These categories are described in detail in Appendix I, where the amounts in the recommended dietary pattern used as a standard are also given. Use of each type of food approximately equal to or slightly less than that recommended is termed "satisfactory," amounts moderately below standard are termed "marginal," and more than moderate deviation below standard is called "unsatisfactory." The limits selected for the three categories were arbitrarily chosen and were determined in large part on the basis of availability of or ease of making substitutions for a specific type of food. Any dietary pattern may be modified to some extent without producing a dietary failure, but in the average American diet, the use of less than the recommended amounts of any of these principal food groups produces a need for careful substitutions or increases in amounts of some other foods in order to obtain the recommended allowances for essential nutri-

ents. Marginal and unsatisfactory ratings indicate a need to improve the use of the specific food or make carefully chosen substitutions.

These qualitative classifications of the use during one week of selected types of foods, for which information on consumption was mostly nonquantitative, afford a good index, it is believed, of dietary habits and indicate fairly well the likelihood of certain dietary deficiencies. It should be emphasized that they do not give precise information on the prevalence of any deficiency. A diet with satisfactory ratings may be deficient in one or more nutrients because the amounts consumed were less than average portions, and a diet with a rating of unsatisfactory for some foods may be adequate because of an unusually high consumption of some alternative foods. Either type of diet probably is not very frequent. In spite of these limitations, the qualitative groupings define the nature of the prevailing dietary pattern and suggest the changes in food habits which are most commonly needed in order to obtain the safe, balanced diet recommended by the Committee on Food and Nutrition.

The frequency of diets which were equal to or slightly below the recommended amounts per week for the five different foods or types of food (satisfactory rating) was as follows:

	Per Cent
Green or yellow vegetables, 6 or more	21
Citrus fruit or tomatoes, 7 or more	36
Milk, 10 or more glasses	51
Eggs, 4 or more	59
Lean meat, etc., 5 or more times	95

Unsatisfactory ratings for amounts per week of specific foods were given to the following percentages of the diets:

	Per Cent
Green or yellow vegetables, 3 or less, or less than 7 vegetables of which 4 or 5 were green or yellow[a]	56

[a] There was 13 per cent of the diets which had 4 or 5 green or yellow vegetables but less than 7 vegetables of all types during one week.

Citrus fruits or tomatoes, 4 or less	49
Milk, 5 glasses or less	33
Eggs, 1 or none	23
Lean meat, 2 times or less	1

It is apparent from the above data, and Figure 2, that vegetables and citrus fruits were the outstanding food deficiencies.

Summary Classification of Individual Diets. It is of interest to know whether persons with good diets in respect to some food groups chose well in other foods or whether the majority had some food deficiency which would impair the dietary adequacy. Therefore, a general or composite qualitative rating of each diet history for one week was made on the basis of ratings for the five foods. As has been discussed, in the usual American dietary, failure to include regularly any one of these food groups among the foods consumed is likely to bring the intake of one or more vitamins or minerals below the allowance recommended. Therefore, the total diet rating is no better than the lowest rating given to any one of the specific food groups. A general rating of unsatisfactory was given if any one of the groups was classified as unsatisfactory; the total diet was rated marginal if any food group was considered marginal but all five were marginal or better; and a diet was classified as satisfactory only if all five food groups were rated satisfactory.

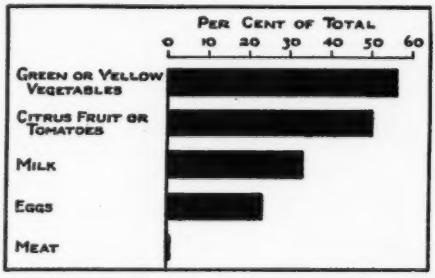

Fig. 2. Percentage of 1,103 diet records for one week in which reported amounts of five different types of food were classified as unsatisfactory.

Among this group of 1,103 industrial workers, only four men reported diets which included approximately the recommended amounts of all five types of food, and nineteen others reported diets which were rated satisfactory. Thus, only 2

per cent of the men had diets which were close to the recommended dietary pattern and furnished regularly dependable food sources for obtaining the recommended allowances of mineral and vitamin elements. The percentage distribution of diets according to their general qualitative ratings is shown in Table 5. Furthermore, only 11 per cent of the men reported marginal diets, and 87 per cent had diets which were unsatisfactory for one or more food groups. Thus, most of the men who had a satisfactory intake of some of the essential foods failed to obtain a balanced diet.

Slightly more than half (55 per cent) of the marginal diets were in this class because of only one food group, and 34 per cent of them were marginal in two food groups. The distributions of marginal diets and unsatisfactory diets according to the number of

Table 5. Distribution of weekly diets according to lowest qualitative rating[1] for any of five food groups and number of food groups in individual diets with the specified lowest rating for 1,103 dietary histories reported by aircraft workers in California, November 1941-February 1942.

General Rating[2] and Number of Food Groups With Same Rating	Number of Diet Records	Per Cent of Total Records in Each Category	Percentage Distribution by Number of Food Groups for Diets With Specified General Rating
Total Records	1,103	100.0	
Satisfactory			
Total	23	2.1	
Marginal			
Total	126	11.4	100.0
1 Food Group	69	6.3	54.8
2 Food Groups	43	3.9	34.1
3 Food Groups	9	0.8	7.1
4 Food Groups	5	0.5	4.0
Unsatisfactory			
Total	954	86.5	100.0
1 Food Group	356	32.3	37.3
2 Food Groups	395	35.8	41.4
3 Food Groups	172	15.6	18.0
4 Food Groups	31	2.8	3.2

[1] *See* Appendix I for description of qualitative classifications for each of the five food groups.
[2] The general rating is the lowest qualitative rating for one or more of the five food groups.

types of food rated marginal or unsatisfactory, respectively, are shown in Table 5 and Figure 3. The sixty-nine diets, or 6 per cent of the 1,103 histories, which were satisfactory with the exception of a marginal rating for one group, were borderline good diets and needed only slight modification.

Included in the unsatisfactory classification were 109 diets, or 10 per cent of all diet histories, which were satisfactory for four of the five foods, but unsatisfactory in one type of food. Nearly two-thirds of these 109 diets, 64 per cent, were unsatisfactory because of too few green or yellow vegetables; 21 per cent because of too little citrus fruits or tomatoes; and 6 per cent because of low milk consumption.

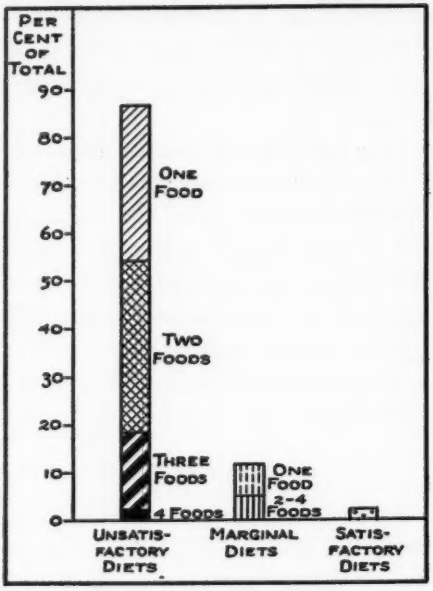

Fig. 3. Percentage of 1,103 diets for one week classified as satisfactory for use of five types of food, as marginal for one or more of five foods, and as unsatisfactory for one or more of five foods.

The total number of diets in which the use of four of the five foods during one week was nearly equal to that recommended was 178, or 16 per cent of the total, compared with 2.3 per cent of the total satisfactory for all five foods. Since the one food failure was vegetables, citrus fruits, or milk in nearly all of these diets, they fell below the recommended diet in foods of special importance as sources of essential nutrients.

In all, 32 per cent of the diets were classified as unsatisfactory be-

cause of only one food group; but 22 per cent also had marginal ratings for one or more food groups. More than one-half of the men (54 per cent) reported diets rated as unsatisfactory in the amounts of two or more types of food. It is apparent that a majority of the men needed to increase their consumption of at least two types of food in order to approximate the recommended dietary pattern.

Since eggs are less essential for obtaining a balanced diet than the other foods, a composite rating based on vegetables, citrus fruit or tomatoes, milk, and meat also was applied to the diets. The omission of eggs changed only slightly the percentages of diets in the different categories. An increase in the number of satisfactory diets from 23 to 43 is of most interest, but on the basis of these four foods, only 3.9 per cent of the men had satisfactory diets. The percentage of marginal diets became 12.6 instead of 11.4, and the percentage of unsatisfactory diets was reduced from 86.5 to 83.3.

FACTORS RELATED TO FOOD HABITS

An analysis of the diet histories was made to determine whether the use of specific types of foods differed for men of various ages and of different durations of residence in California; and the possible relation of type of eating place to the quality of the diet also was considered.

Time in California. For men who had resided in California for five years or longer, the proportions of diets which were classified as satisfactory, marginal, and unsatisfactory were the same as for those who had been in California less than one year. There were slight differences in the percentages of men with unsatisfactory use of specific foods, as is shown in Table 6. Thus, the diets of men in California less than one year were somewhat more frequently low in the amount of green or yellow vegetables and in the number of eggs, but were slightly less frequently unsatisfactory in the amount of milk and of citrus fruits than the diets of men in California a

Classification of Diet[1]	Per Cent of Diets of Employes in California for Specified Time			Number of Diets of Employes in California for Specified Time		
	Less Than 1 Year	1 to 4 Years	5 Years or Longer	Less Than 1 Year	1 to 4 Years	5 Years or Longer
Total Records	100.0	100.0	100.0	340	292	441
General Rating						
Satisfactory	2.4	2.1	2.0	8	6	9
Marginal	11.2	10.3	11.3	38	30	50
Unsatisfactory	86.5	87.7	86.6	294	256	382
Unsatisfactory						
One Food Group	31.8	32.2	32.2	108	94	142
Two Food Groups	35.3	37.0	36.1	120	108	159
Three Food Groups	15.6	16.4	15.4	53	48	68
Four Food Groups	3.8	2.1	2.9	13	6	13
Specific Foods Unsatisfactory						
Green or Yellow Vegetables	62.9	53.8	51.5	214	157	227
Citrus Fruit or Tomatoes	44.1	51.7	52.2	150	151	230
Milk	30.9	33.6	36.1	105	98	159
Eggs	26.2	24.0	21.5	89	70	95
Meat	0.3	0.7	1.1	1	2	5

[1] *See* Appendix I.

Table 6. Duration of residence in California in relation to quality of total diet and frequency of unsatisfactory ratings for use of specific foods among weekly dietary histories reported by aircraft workers, November 1941-February 1942.

longer time. None of these differences was large, but it is of interest that men who had most recently arrived in California ate the most citrus fruit.

Age in Years. Dietary differences by age group were greater than according to time in California. Young men under 25 years of age had diets classified as unsatisfactory for one or more foods about as frequently as the older men; but as age increased, there was an increase in the number of types of food used in insufficient amounts. This is shown in Table 7 and in Figure 4. Thus, about 39 per cent of the diets of men under 25 years of age were unsatisfactory because one food was neglected, 29 per cent of diets of men aged 25 to 34 years, and 21 per cent for men 35 years of age or older. On the other

Classification of Diet[1]	Per Cent of Diets of Employes of Specified Age			Number of Diets of Employes of Specified Age		
	Under 25 Years	25–34 Years	35 Years or Older	Under 25 Years	25–34 Years	35 Years or Older
Total Records	100.0	100.0	100.0	449	421	124
General Rating						
Satisfactory	2.0	1.9	3.2	9	8	4
Marginal	13.4	10.2	8.1	60	43	10
Unsatisfactory	84.6	87.9	88.7	380	370	110
Unsatisfactory						
One Food Group	38.5	29.5	21.0	173	124	26
Two Food Groups	32.5	36.3	41.1	146	153	51
Three Food Groups	10.9	18.5	23.4	49	78	29
Four Food Groups	2.7	3.6	3.2	12	15	4
Specific Foods Unsatisfactory						
Green or Yellow Vegetables	54.3	57.2	54.0	244	241	67
Citrus Fruit or Tomatoes	44.1	50.4	54.8	198	212	68
Milk	23.2	39.9	51.6	104	168	64
Eggs	24.7	23.8	24.2	111	100	30
Meat	0.7	0.7	1.6	3	3	2

[1] *See* Appendix I.

Table 7. Age of employe in relation to quality of total diet and frequency of unsatisfactory use of specific foods from dietary histories for aircraft workers in California, November 1941-February 1942.

hand, about 14 per cent of the diets of men under 25 years of age were unsatisfactory for three or four food groups compared with 22 per cent and 27 per cent in the older age groups respectively.

The specific foods in which the diets of older men were more often unsatisfactory were milk and citrus fruits or tomatoes.

Eating Place and Age. Since more of the younger men ate at restaurants or boarded, a comparison was made of the consumption of different foods according to eating place as well as by age. The percentages of diets classified as unsatisfactory for each type of food are shown in Table 8 and in Figure 5. There were only 15 men over 35 years of age who ate in a restaurant or boarded, and these have been omitted.

The use of green or yellow vegetables was similar for all groups,

and from 50 to 58 per cent of diets were unsatisfactory in this food group.

Men under 25 years of age who ate at home had the best consumption of citrus fruits or tomatoes, but 40 per cent of them had diets classified as unsatisfactory for this type of food. In the same age group, 52 per cent of the diets were unsatisfactory for citrus fruits when the men ate in a restaurant or boarded, and 50 to 55 per cent of the diets of older men were unsatisfactory for citrus fruit if they ate at home or in a restaurant.

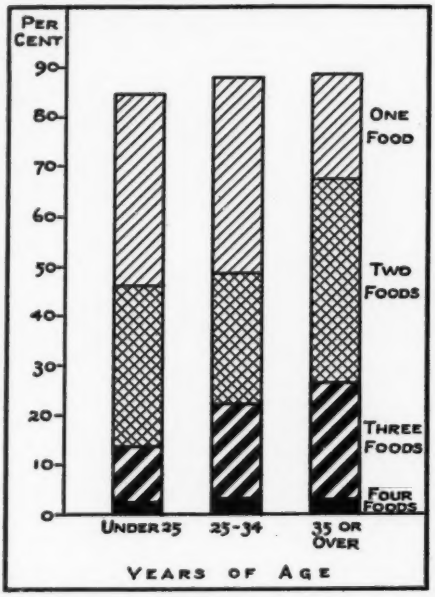

Fig. 4. Age of employe and the percentages of diets for one week classified as unsatisfactory because of insufficient amounts of one or more of five important food groups.

Milk consumption was considered unsatisfactory for only 22 per cent of men under 25 years of age who ate at home and for 25 per cent of those eating in restaurants or boarding houses, compared with 51 per cent of diets of men 35 years of age or older who ate at home. Diets were unsatisfactory in milk for 41 per cent and 33 per cent of men aged 25 to 34 years who ate at home and boarded, respectively. The consumption of milk differed more by age of the employe than consumption of any of the other types of food.

B. Nutritive Content of Two-Day Diets

The consumption level for calories and eight essential nutrients

Classification of Diet[1]	Per Cent of Diets of Employes in Specified Category					
	Meals at Home			Restaurant or Boarding House		
	Under 25 Years	25–34 Years	35 Years or Older	Under 25 Years	25–34 Years	35 Years or Older
Total Records	100.0	100.0	100.0	100.0	100.0	
General Rating						
Satisfactory	2.1	1.7	2.8	1.9	3.3	
Marginal	11.5	10.0	7.3	16.7	11.7	
Unsatisfactory	86.4	88.4	89.9	81.5	85.0	
Specific Foods Unsatisfactory						
Green or Yellow Vegetables	56.8	58.2	55.0	50.0	51.7	
Citrus Fruit or Tomatoes	39.7	49.6	55.0	51.9	55.0	
Milk	22.0	41.0	50.5	25.3	33.3	
Eggs	21.3	23.5	24.8	30.9	25.0	
Meat	1.0	0.6	1.8	0	1.7	
Number of Diet Histories	287	361	109	162	60	15

[1] *See* Appendix I.

Table 8. Age and eating place of employe in relation to quality of total diet and frequency of unsatisfactory use of specific foods from dietary histories for aircraft workers in California, November 1941-February 1942.

by these employes is revealed by the estimates of the average daily amounts of different nutrients furnished by the food reported in the two-day quantitative record. The accuracy of these estimates of nutritive content of foods consumed can be described as fairly good approximations. Both the errors in reporting the quantity of each food eaten and the errors in average values for nutrient content of each food tend to be compensating, and the total nutrient value calculated for a complete two-day diet usually will have a smaller error than the errors in reported quantity and in nutrient values for individual food items. For a few diets, the error of the total value probably was significantly large due to omission of some food or general underestimation or overestimation of portions. In general, the calculated nutritive content is believed to afford a sufficiently accurate index of the consumption level of the various nutrients for

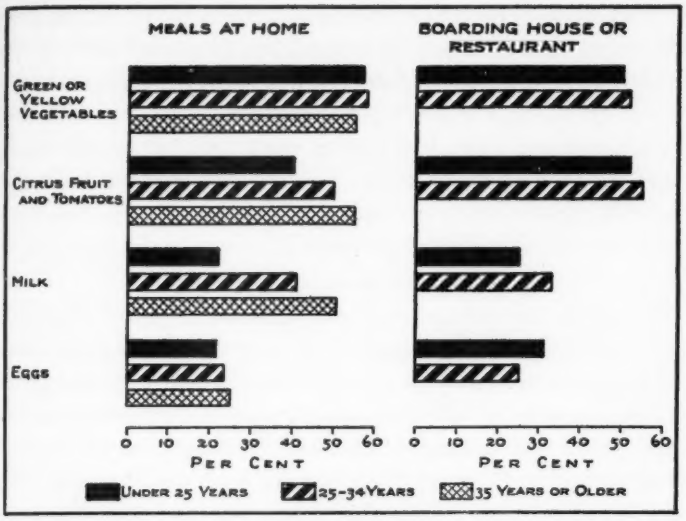

Fig. 5. Age of employe and eating place in relation to percentages of diets for one week classified as unsatisfactory for amounts of specific types of food.

several broad classifications of individual diets which will disclose the approximate frequency of deficiencies of different nutrients as judged by recommended allowances.

The average daily nutritive content of a two-day diet will not always disclose dietary deficiencies that would be revealed in a longer period. In the previous discussion of quality of food habits, it was emphasized that certain types of food should be eaten regularly, and daily consumption of some foods was the standard for a good diet. In the two-day diet, inadequate amounts of any nutrients give evidence that the reported diet fell below the recommended allowances on one or both days; but adequate amounts for two days do not necessarily indicate that the person was obtaining a good diet regularly. Thus, the frequency of deficient diets will tend to be somewhat lower for a two-day period than for an entire week.

The 250 two-day diets for which the content of specific nutrients

is presented were selected to represent the three-month period from November 15 to February 15. Records included were taken in the last week of November, and the first half of December, of January, and of February. The diet reports used always were for two days on which the employe had been at work. In addition, no record was used if the informant stated that there was anything "unusual" about the reported diet in response to a specific question to determine whether or not it was a typical diet.

DAILY INTAKE OF SPECIFIC NUTRIENTS

The intake of each nutrient was classified in one of four categories according to the proportion of the recommended allowance which was furnished by the reported two-day diet. These categories are: A) equal to or greater than allowance; B) not more than 20 per cent less than allowance; C) from one-third to 20 per cent less than allowance; D) more than one-third less than allowance. The allowances adopted by the Committee on Food and Nutrition "were planned to provide a reasonable margin of safety" and were not minimum requirements. For purposes of this analysis, two-thirds of the allowance was adopted as a minimum intake below which a diet might be considered probably deficient. The limits of

Table 9. Percentages of diets in which the estimated content for eight different nutrients was various proportions of the recommended allowances, based on 250 two-day diets reported by aircraft employes in California, November 1941-February 1942.

Nutrient	Percentage of Diets With Specified Amount					Daily Allowance Recommended
	Total	Percentage of Recommended Allowance				
		100 or More	80–99	67–99	Under 67	
Protein	100.0	85.2	10.0	4.0	0.8	70 Gms.
Iron	100.0	78.0	13.2	4.8	4.0	12 Mg.
Niacin	100.0	70.0	18.4	4.4	7.2	18 Mg.
Vitamin A	100.0	58.0	16.8	10.4	14.8	5,000 I.U.
Thiamin	100.0	53.6	20.4	12.0	14.0	1.8 Mg.
Calcium	100.0	52.0	12.4	10.8	24.8	0.80 Gm.
Ascorbic Acid	100.0	33.2	10.0	10.8	46.0	75.0 Mg.
Riboflavin	100.0	29.2	16.0	11.6	43.2	2.7 Mg.

21 to 33 per cent less than the allowance were arbitrarily chosen for a marginal diet, which may be deemed "unsafe" and in need of improvement. A diet which furnished at least 80 per cent of the allowances for specific nutrients has been considered reasonably satisfactory.[4]

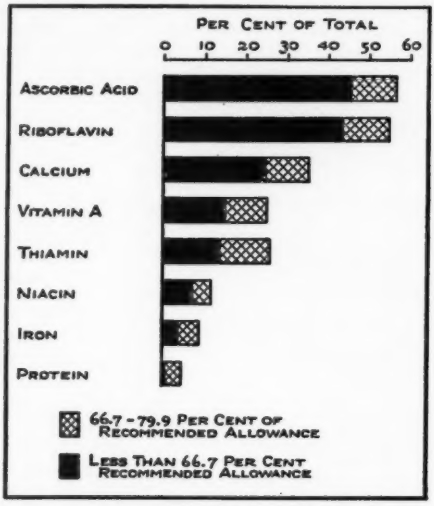

Fig. 6. Percentages of 250 diets for two days in which the estimated amounts of seven different nutrients were less than 80 per cent and less than 67 per cent of the recommended allowance for a specific nutrient.

For the various nutrients, there was a great difference in the percentages of diets which met the recommended allowances. The percentage distributions of the diets according to the four classes are given in Table 9 for protein, calcium, and iron, and five vitamins. Protein was most often obtained in adequate amounts and 85 per cent of the diets furnished the allowance or more. The iron allowance was met by 78 per cent of the diets and the niacin allowance by 70 per cent. The allowances for vitamin A, thiamin, and calcium were met by 58, 54, and 52 per cent of the diets, respectively. The ascorbic acid and riboflavin content met the allowances in 33 and 29 per cent of the diets, respectively.

[4] The full allowance for nutrients is highly desirable. The level for a satisfactory diet adopted here is based on the following considerations: (1) a conservative intake requirement was desired which would not overestimate the deficiencies in diet; (2) some reduction in content of foods for loss in cooking was made in computing vitamin values and allowances of the Committee on Food and Nutrition "do not allow for any extensive losses in cooking;" (3) underestimate of quantity and errors of omission in reporting no doubt affected some diet histories; (4) individual differences in requirements for various nutrients exist.

Table 10. Classification of diets according to number and type of nutrients furnished at intake level of specified minimum for any of 7 nutrients, including calcium, iron, vitamin A, ascorbic acid, niacin, riboflavin, and thiamin. (Class A = allowance or more; Class B = 80-99 per cent of allowance; Class C = 67-79 per cent of allowance; Class D = less than 67 per cent of allowance.)

Number of Nutrients in Lowest Intake Class Found in Individual Diet	Number	Per Cent of Total
Total Diets	250	100.0
Class A, 7 Nutrients	19	7.6
Class B, 1 or More Nutrients	24	9.6
Class C, 1 or More Nutrients	28	11.2
1 Nutrient Only	24	9.6
2 Nutrients	4	1.6
Class D, 1 or More Nutrients	179	71.6
1 Nutrient Only	74	29.6
2 Nutrients	47	18.8
3 Nutrients	32	12.8
4 Nutrients	14	5.6
5 Nutrients	7	2.8
6 Nutrients	5	2.0
Specific Nutrients in Lowest Intake Class		
Class C		
1 Nutrient		
Riboflavin	11	4.4
Ascorbic Acid	10	4.0
Calcium, Thiamin, Niacin, One Each	3	1.2
2 Nutrients		
Riboflavin and: Ascorbic Acid, Thiamin, Vitamin A, One Each	3	1.2
Ascorbic Acid and Vitamin A	1	0.4
Class D		
1 Nutrient		
Ascorbic Acid	47	18.8
Riboflavin	16	6.4
Calcium	5	2.0
Vitamin A	5	2.0
Iron	1	0.4
2 Nutrients		
Riboflavin and Ascorbic Acid	16	6.4
Riboflavin and Calcium	12	4.8
Riboflavin and Thiamin	4	1.6
Riboflavin and Vitamin A	3	1.2
Riboflavin and Niacin	3	1.2

Table 10. (Continued)

Number of Nutrients in Lowest Intake Class Found in Individual Diet	Number	Per Cent of Total
Specific Nutrients in Lowest Intake Class (Continued)		
2 *Nutrients—Continued*		
Ascorbic Acid and Thiamin	3	1.2
Ascorbic Acid and Vitamin A	2	0.8
Ascorbic Acid and Calcium	2	0.8
Calcium and Thiamin	2	0.8
3 *Nutrients*		
Riboflavin, Ascorbic Acid, and Calcium	10	4.0
Riboflavin, Ascorbic Acid, and Vitamin A	6	2.4
Riboflavin, Calcium, and Vitamin A	3	1.2
Riboflavin, Thiamin, and Niacin	3	1.2
Other Combinations	10	4.0
4 *Nutrients*		
Riboflavin, Ascorbic Acid, Calcium, and Vitamin A	7	2.8
Riboflavin, Ascorbic Acid, Calcium, and Thiamin	4	1.6
Other Combinations	3	1.2
5 *Nutrients*		
Riboflavin, Ascorbic Acid, Calcium, Niacin, and One Other	4	1.6
Other Combinations	3	1.2
6 *Nutrients*		
Riboflavin, Calcium, Niacin, Thiamin, and Two Others	5	2.0

The relative frequency of diets with less than 80 per cent of allowances for the different nutrients is portrayed in Figure 6. The order is approximately the reverse of that found for the percentages of diets which met the allowances, as the percentage of diets within 20 per cent of the allowance was not large for any nutrient. Diets were deficient by more than one-third of the allowance in the following descending order of frequency for specific nutrients: ascorbic acid, 46 per cent; riboflavin, 43 per cent; calcium, 25 per cent; vitamin A,[5] 15 per cent; thiamin, 14 per cent; niacin, 7 per cent; and iron, 4 per cent. Less than 1 per cent of the diets furnished less than two-thirds of the protein requirement.

Multiple Nutrient Deficiencies. For the two minerals and five

[5] The very high content of vitamin A of some vegetables may make an average intake for a two-day period unusually high and atypical of the consumption level over a longer period.

vitamins, deficiencies of more than one-third of allowance averaged 1.54 per person; and deficiencies of more than 20 per cent averaged 2.19 per person. But for those employes whose diets were deficient by more than 20 per cent for at least one nutrient, the average number of deficiencies was 2.61, and for employes with diets deficient by one-third for one or more nutrients, the average number of nutrient deficiencies was 2.15.

Of greater interest than the average number of deficiencies is the distribution of diets according to the number of nutrients which were obtained in inadequate amounts. This information is given in Table 10. Only 8 per cent of these men had obtained a diet which furnished all seven nutrients in amounts equal to or greater than the allowances; and not quite 10 per cent had diets which furnished 80 to 99 per cent of the recommended allowances. Thus, 17 per cent of the men had moderately good or excellent diets. The other 83 per cent of the men needed some improvement in their diets. This includes the 11 per cent of the employes who had marginal diets or diets in which the amount of one or more nutrients was from 67 to 79 per cent of the allowance; and the remaining 72 per cent who obtained less than 67 per cent of the allowance for at least one of the seven nutrients.

The marginal diets were most often low in only one nutrient, but a few had two nutrients in the marginal classification. The nutrient in which these marginal diets failed was either ascorbic acid or riboflavin in most instances.

The number of nutrients in individual diets which were less than two-thirds of allowances ranged from one to six. Thirty per cent of all diets had less than two-thirds of the allowance for only one nutrient; 19 per cent had this degree of deficiency for two nutrients; 13 per cent for three nutrients, and 10 per cent for four to six nutrients.

When the diet was deficient in only one nutrient, the specific nutrient involved was ascorbic acid in nearly two-thirds and ribo-

flavin in slightly over one-fifth of such diets. When multiple deficiencies occurred, ascorbic acid was one of the deficiencies in nearly two-thirds of these diets also; but riboflavin was part of the multiple deficiency combinations in 84 per cent of the diets with two or more nutrients supplied in amounts less than two-thirds of allowances. Calcium was one of the deficient nutrients in 54 per cent of the multiple deficiency diets, but was the sole deficiency in only 2 per cent of all diets or 6.8 per cent of single deficiency diets.

The rare occurrence of thiamin, vitamin A, niacin, and iron as single dietary deficiencies or of combinations of these nutrients without riboflavin, calcium, or ascorbic acid also being deficient suggests two observations on the eating habits of this group. A small, but significant, proportion of these men apparently ate a very restricted diet, and a generally increased consumption as well as improved food choices probably was needed. For most of the men, a better consumption of milk and of citrus fruits, tomatoes, and certain green vegetables would correct the major deficiencies of riboflavin, calcium, and ascorbic acid and raise the intake of most other nutrients. Conversely, if an average mixed diet contains sufficient amounts of riboflavin and ascorbic acid, it will seldom be deficient in the other nutrients.

ENERGY VALUE OF DIETS

The estimated number of calories in the total amount of food reported is shown in Table 11. For 34 per cent of these men the estimated energy value equalled or exceeded the 3,000 calories daily recommended for the average man with moderate activity. The medium number of calories for the group was about 2,675; and about one-fourth of the men had diets which furnished less than 2,200 calories daily.

A better indication of the adequacy of these diets in calories may be obtained if the intake is considered in relation to the individual's requirement. The basal requirement for each employe was esti-

mated on the basis of age, height, and weight from tables published by Boothby, Berkson, and Dunn (6). The percentage of this basal requirement which was furnished by the total food reported was computed for each individual. The distributions of these diets according to the percentage of basal requirement is given in Table 12.

Table 11. Average number of calories per day estimated for two-day diet histories of 250 aircraft workers in California, November 1941—February 1942.

Number of Calories	Number of Diets	Per Cent of Total
TOTAL	250	100.0
Less Than 1,800	22	8.8
1,800–2,199	44	17.6
2,200–2,599	50	20.0
2,600–2,999	50	20.0
3,000–3,399	44	17.6
3,400–3,799	23	9.2
3,800–4,199	7	2.8
4,200–4,599	6	2.4
4,600 or More	4	1.6

About one-fourth of the men reported amounts of food for two days which furnished 180 per cent or more of their estimated basal requirement. This amount should be adequate for men working eight hours a day at moderately active work. For another 36 per cent of the men, the caloric intake was from 140 to 179 per cent of basal requirements. But nearly 40 per cent of the men reported diets which would furnish less than 140 per cent of basal metabolic needs, and this level of caloric intake would be insufficient for men engaged in work involving physical activity.

As the quantity of food eaten was reported from memory and estimated, it would be easy to conclude that these low estimates of caloric intake were the result of incomplete diet records or gross underestimation. No doubt, some men did have more than the estimated number of calories, and it is very unlikely that any men were consuming less than their basal need, although 5 per cent of them reported such a diet for a two-day period. But even if considerable allowance is made for omissions of some food items or underestimates of quantity, the evidence is strong that a consider-

able number of these men were eating low-calorie diets which were below a consumption level believed to be adequate. Furthermore, the frequency of low-calorie diets among this group is in line with the findings of other dietary studies in which data were collected by the family inventory method or by weighing the foods eaten. Thus, a study in Toronto (2c) of individual diets for one week, based on weighed amounts of food, reported that ninety-three male wage earners had an average daily caloric intake of 2,540 calories; and a study in Halifax (2a) showed that male workers in eighty-two families had an average consumption of 2,622 calories per day. Considerable evidence is available to indicate that it is not unusual for wage earners to eat a diet with less energy value than is deemed desirable.

Table 12. Calories furnished by two-day diets expressed as the percentage of individual basal caloric requirement.

Per Cent of Basal Requirement	Number of Diets	Per Cent of Total
Total	250	100.0
Less Than 100.0	13	5.2
100.0–119.9	37	14.8
120.0–139.9	47	18.8
140.0–159.9	46	18.4
160.0–179.9	43	17.2
180.0–199.9	29	11.6
200.0–219.9	19	7.6
220.0–239.9	5	2.0
240.0 or More	11	4.4

For the employes in this Study, these data suggest that from one-fourth to one-third of the men probably had insufficient calories in the two-day period for which the quantitative diet was reported. The significance of a low intake of calories would depend on whether it was typical or usual for the individual.

C. Vitamin and Mineral Supplements

The use of concentrated or synthetic vitamin and mineral preparations was not extensive among these employes. The men who reported taking any prepared supplement comprised only 8.8 per cent of the group. This included only six persons, or 0.5 per cent who reported a mineral supplement. The majority of those who

Vitamin or Mineral in Supplement	Number of Persons	Per Cent	
		Of Total Persons	Of Those Taking a Supplement
Total Persons	1,103	100.0	
Total—1 or More Types of Supplement	97[1]	8.8	100.0[1]
Vitamin A (+ or − D)	48	4.4	49.5
B Complex	39	3.5	40.2
Yeast	12	1.1	12.4
Thiamin	14	1.3	14.4
Ascorbic Acid	12	1.1	12.4
Calcium	4	0.4	4.1
Iron or Liver Extract	2	0.2	2.1
Other and Not Specific	11	1.0	11.3

[1] Numbers of persons taking specified supplement do not add to total because many took more than one type of supplement.

Table 13. Frequency of use of specific vitamin or mineral supplements among a group of aircraft employes in California.

took any vitamin or mineral product were taking more than one kind, usually a multiple vitamin product.

Both vitamin A and B complex, separately or in a combination product, were taken by slightly over one-fourth of those taking vitamins and by about 2.4 per cent of all persons interviewed. Detailed information on use of supplements is given in Table 13. Vitamin A, either alone or with other vitamins,[6] was reported by 4.4 per cent of the men; B complex, alone or with other vitamins or minerals, was reported by 3.5 per cent; and yeast by 1.1 per cent. Thiamin alone was being taken by 1.2 per cent of the men, and no other single vitamin was taken by more than one or two persons. Some ascorbic acid was taken by 1.1 per cent of the men, and all but one person obtained his ascorbic acid from a multi-vitamin preparation. Of the six men who reported any mineral supplement, four were taking calcium, and all of these also were taking one or more vitamins; two were taking iron or liver extract.

[6] These were vitamins other than vitamin D. Most vitamin A products reported included D, but a number of men were unable to give definite information as to the trade name or content of product taken.

Summary

Diet histories on the consumption of selected foods during one week were collected for 1,103 aircraft workers in Southern California between November 15, 1941 and February 15, 1942. The reported use of each of five foods or food groups was compared with amounts recommended in the dietary pattern prepared by the National Research Council, Committee on Food and Nutrition with the following results:

(1) Percentages of diets which included amounts per week equal to or slightly below that recommended were:

	Per Cent
Green or yellow vegetables, 6 or more	21
Citrus fruits or tomatoes, 7 or more	36
Milk, 10 or more glasses	51
Eggs, 4 or more	59
Lean meat, fish, etc., 5 or more times	95

(2) percentages of diets which included amounts definitely below that recommended were:

	Per Cent
Green or yellow vegetables, 3 or less—43 per cent Less than 7 vegetables, with 5 or less green or yellow—13 per cent	56
Citrus fruits or tomatoes, 4 or less	49
Milk, 5 glasses or less	33
Eggs, 1 or none	23
Lean meat, etc., 2 or less times	1

When amounts of all five foods in an individual diet are considered, it is found that: 2 per cent of the diets included amounts of each of the five foods as described in (1) above; 11 per cent had smaller amounts for one or more foods but none as low as described in (2) above; and 87 per cent of the diets had amounts as low as described in (2) above for one or more food groups. The latter group

of 87 per cent included: 32 per cent of diets low in one food group, 36 per cent low in two food groups, 16 per cent low in three food groups, and 3 per cent low in four food groups.

There was little difference in the diets of men recently arrived in California and those who had lived there five years or longer.

Young men had somewhat better diets than the older men. Men under 25 years of age drank more milk and ate more citrus fruits than those 25 years or older, but had a similar consumption of green and yellow vegetables and eggs.

Two hundred and fifty complete two-day diet records, for which estimated amounts of each food were reported, were analyzed to obtain approximate values for their nutritive content in calories, protein, calcium, iron, vitamin A, ascorbic acid, niacin, thiamin, and riboflavin. The percentages of these diets in which the amount of a specific nutrient was less than two-thirds of the recommended daily allowance were: protein, 0.8 per cent; iron, 4.0 per cent; niacin, 7.2 per cent; thiamin, 14.0 per cent; vitamin A, 14.8 per cent; calcium, 24.8 per cent; riboflavin, 43.2 per cent; ascorbic acid, 46.0 per cent.

Among the 250 two-day diets, there was 71.6 per cent in which one or more of the mineral and vitamin nutrients was less than two-thirds of the daily allowance. The average number of nutrients below this intake level was 2.15.

The median caloric value was 2,675 calories per day, and only 34 per cent of the diets furnished an estimated 3,000 calories or more per day.

Appendix I

Description of qualitative classes used in rating weekly diet histories. A is satisfactory, B is marginal, and C is unsatisfactory.

Milk:

A—10 or more glasses
B—6-9 glasses
C—5 or less glasses

Vegetables—Green or Yellow:

A—6 or more green or yellow vegetables
B—4 or 5 green or yellow vegetables, at least 7 total for all kinds
C—3 or less green or yellow vegetables, or less than 7 total with 4 or 5 green or yellow vegetables

Citrus Fruit and Tomato:

A—Citrus fruits and tomatoes—7 or more
B—Citrus fruits and tomatoes—5 or 6
C—Citrus fruits and tomatoes—4 or less

Eggs:

A—4 or more
B—2 or 3
C—1 or 0

Lean Meat, Fish, or Poultry:

A—5 or more times
B—3 or 4
C—2 or less

The dietary "pattern" to meet recommended allowances outlined by the Committee on Food and Nutrition, National Research Council, is as follows:

Milk, adults—1 pint daily
Vegetables, 2 servings daily—1 green or yellow
Fruit, 2 servings daily—1 citrus or tomato and 1 other
Eggs, 3 or 4 times per week
Meat, 1 serving daily
Whole grain or "enriched" cereal and bread, at least half of the intake
Butter, or fortified oleomargarine (100-500 calories)
Potato, 1 or more servings

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1940 CENSUS DATA ON NUMBER OF YEARS OF SCHOOL COMPLETED[1]

HENRY S. SHRYOCK, JR.

UNTIL 1940 the United States had taken no comprehensive inventory of the formal educational attainment of its people. On the amount of schooling possessed by an American, we lacked quantified knowledge essential to an understanding of his functioning in his various roles of worker, consumer, voter, and member of a reading and listening public. We did not know how these attainments varied among the people of different sections of the country and among different classes. There was no way of getting a nation-wide picture of the relationship of education to fertility, to age at marriage, to occupation, or to income, or of the educational selections involved in the process of internal migration.

From tabulations of the replies to the 1940 Census inquiry on number of years of school completed, we are beginning to get information on some of these questions. The data tabulated or being tabulated provide not only distributions by educational attainment for thousands of separate areas and groups but also an extremely useful index of social-economic status, applicable to any adult, that can be used in the analysis of many other variables.

For a definition of the term "last year of school completed" as used in the Census, the reader is referred to page 384, Appendix A. (Here he will also find a discussion of the advantages and limitations of this index of educational status. Furthermore, in Appendix B, a brief outline of the materials involving "last year of school completed" is presented.) It is necessary to state in advance, however, that practically all of the statistics so far available are limited

[1] Revision of a paper read before the Population Association of America, May 1, 1942. The writer is indebted to Miss Lillian Hunvald and Mr. Joel Williams of the Population Division of the Census Bureau for assistance in the compilation of many of the data and for critical suggestions.

to the population 25 years old and over without any further classification by age. Thus they describe the existing educational level in an area or group among persons practically all of whom have completed their formal education, but in disregarding age they obscure an important causal factor in the differences observed.[2]

The United States as a Whole. We may first describe the situation in the country as a whole in 1940.[3] The median number of years of school completed by persons 25 years old and over was 8.4.[4] This is equivalent to the completion of elementary school plus the completion of part of the first year of high school. The proportion that had never completed as much as one year of formal schooling was 3.7 per cent. (If we make the extreme assumption that all persons for whom education was not reported had never completed one full year of school, then this proportion would be increased to 5.1 per cent. This percentage is certainly too high, but it indicates the possible range.) A large potential group for adult education programs would seem to be represented by the 10,104,612 persons, or 13.5 per cent, who had completed fewer than five years. Almost a quarter (24.1 per cent) of the population aged 25 years or over had finished at least high school, 10.0 per cent had completed at least one year of college, and 4.6 per cent were college graduates. (*See* Table 1.)

[2] The extent to which educational attainment has been improving during the past fifty years or so is shown in the following table, which presents figures from a .5 per cent sample tabulation of the white population:

Age	*Median School Years Completed*
25 to 34 years	10.5
35 to 44 years	8.7
45 to 54 years	8.2
55 to 64 years	7.9
65 years and over	7.6

[3] A somewhat fuller account is given in: United States Bureau of the Census: *Educational Attainment of the Population 25 Years Old and Over in the United States: 1940*, Series P-10, No. 8, April 23, 1942. Tables 1 and 2 of the present article are condensed from the tables of this release.

[4] Medians are expressed in terms of a continuous series of numbers representing years completed. For example, the completion of the first year of high school is indicated by 9 and of the last year of college by 16.

Urban-Rural Differences. The median number of school years completed was 8.7 for the urban population, 8.4 for the rural-nonfarm population, and 7.7 for the rural-farm population. These same relations existed for each sex of each race-nativity group (native white, foreign-born white, Negro, and other races) except that the medians were about the same for foreign-born whites regardless of type of residence. With the distribution of all persons 25 years of age and over as a standard, medians have been computed standardized for race-nativity and sex. The order of medians for the three areas is not changed thereby, and the crude and standardized medians never differ by more than two-tenths of a school year. It is not possible to standardize for age at this time.

If the educational level of the three residence groups is measured by computing for each the proportion (unstandardized) who have never completed as much as one full school year, the results are similar. For native whites, Negroes, and other nonwhite races, the percentage having no years of school completed was highest for the rural-farm population and lowest for urban residents. For foreign-born whites, however, the relationship is reversed, the urban areas having had the highest proportion unschooled in their population and the rural-farm areas the lowest. Urban residents ranked highest in the proportion of college graduates in their population, 5.8 per cent of those reporting, as compared with 4.3 per cent for rural-nonfarm and 1.3 per cent for rural-farm groups. The three residence groups ranked in this same order for each of the race-nativity groups.

In Figure 1, the proportion completing at least the indicated number of years of school is compared graphically among the three areas—urban, rural-nonfarm, and rural-farm. These cumulative proportions are standardized for race-nativity and sex and have as a base the number reporting education. (All differences between crude and standardized proportions are slight; the only noteworthy change being that the standardized per cent of persons completing

Sex and Years of School Completed	United States					Urban					Urban				
	All Classes	Native White	Foreign-born White	Negro	Other Races	All Classes	Native White	Foreign-born White	Negro	Other Races	All Classes	Native White	Foreign-born White	Negro	Other Races
Both Sexes															
Persons 25 Years Old and Over	74,776	57,038	10,961	6,491	285	45,229	34	6	3,6						
No School Years Completed	2,800	764	1,336	646	54	1,606		9	24						
Grade School: 1–4 Years	7,305	3,458	1,764	2,034	49	3,472	1	0	85						
5 and 6 Years	8,515	5,513	1,569	1,393	40	4,465	2	6	77						
7 and 8 Years	25,898	20,559	3,988	1,287	64	15,064	10	5	90						
High School: 1–3 Years	11,182	9,842	761	550	29	7,186	6	4	41						
4 Years	10,552	9,448	808	268	28	7,525	6	6	22						
College: 1–3 Years	4,075	3,737	211	118	8	2,734	2	3	9						
4 Years or More	3,407	3,068	252	81	7	2,586	2	4	6						
Not Reported	1,042	649	272	114	7	592		7	5						
Median School Years Completed	8.4	8.8	7.3	5.7	6.8	8.7		4	6.8						
Male															
Persons 25 Years Old and Over	37,463	28,327	5,787	3,162	187	21,988	15	5	1,69						
No School Years Completed	1,471	432	655	353	31	784		2	12						
Grade School: 1–4 Years	4,079	1,979	969	1,097	34	1,829		4	43						
5 and 6 Years	4,400	2,891	834	648	26	2,231	1	5	36						
7 and 8 Years	13,239	10,540	2,079	578	42	7,430	5	8	41						
High School: 1–3 Years	5,333	4,700	390	224	19	3,388	2	2	17						
4 Years	4,507	3,981	401	108	18	3,180	2	8	9						
College: 1–3 Years	1,824	1,645	125	48	6	1,272	1	4	3						
4 Years or More	2,021	1,789	187	41	5	1,554	1	9	3						
Not Reported	588	370	149	65	5	319		4	2						
Median School Years Completed	8.3	8.6	7.3	5.3	6.9	8.6		4	6.5						
Female															
Persons 25 Years Old and Over	37,313	28,712	5,174	3,329	98	23,241	17	1	1,92						
No School Years Completed	1,329	333	680	293	22	823		7	11						
Grade School: 1–4 Years	3,226	1,479	796	937	14	1,643		6	42						
5 and 6 Years	4,115	2,622	735	745	13	2,234	1	3	40						
7 and 8 Years	12,659	10,018	1,909	709	22	7,634	5	7	49						
High School: 1–3 Years	5,849	5,142	372	326	10	3,798	2	2	24						
4 Years	6,044	5,467	407	160	10	4,344	3	7	13						
College: 1–3 Years	2,251	2,093	86	70	2	1,461	1	9	5						
4 Years or More	1,386	1,279	65	40	1	1,031		5	3						
Not Reported	454	279	123	59	2	273		4	2						
Median School Years Completed	8.5	9.0	7.3	6.1	6.7	8.8		3	7.0						

Table 1. Persons 25 years old and over, by years of school completed, race, and sex, for the United States, urban and rural, 1940. (Population in thousands.)

at least one year of school is slightly higher for the urban than for the rural-nonfarm population, whereas on the basis of the crude percentages the reverse is true.)

Race-Nativity Differences. Striking differences are observable among the four race-nativity classes. The unadjusted median num-

Urban			Rural–Nonfarm					Rural–Farm				
	Negro	Other Races	All Classes	Native White	Foreign-born White	Negro	Other Races	All Classes	Native White	Foreign-born White	Negro	Other Races
	3,622	114	14,754	12,316	1,318	1,056	64	14,793	11,985	887	1,813	107
	240	14	500	211	144	134	11	693	300	93	272	28
	859	16	1,512	899	226	375	11	2,321	1,332	168	800	21
	771	13	1,755	1,326	193	226	10	2,295	1,744	138	396	17
	900	26	5,113	4,452	471	174	15	5,721	5,114	372	212	23
	416	13	2,243	2,083	86	67	7	1,753	1,637	41	66	9
	225	17	1,909	1,789	89	26	5	1,118	1,062	32	18	6
	93	5	838	795	28	14	2	503	480	11	11	1
	66	5	625	584	31	10	1	196	184	7	5	1
	53	3	258	177	50	29	2	193	133	24	33	3
	6.8	7.9	8.4	8.6	7.3	5.0	6.7	7.7	8.0	7.2	4.1	5.4
	1,695	85	7,578	6,270	733	538	38	7,897	6,384	519	929	65
	122	10	279	119	79	74	6	408	183	54	157	15
	439	13	868	519	134	209	7	1,382	817	101	450	14
	362	11	930	708	108	109	6	1,238	970	81	178	10
	410	19	2,688	2,345	254	80	9	3,121	2,802	217	89	14
	170	10	1,093	1,016	44	28	4	852	798	23	25	5
	91	11	838	780	45	10	3	489	461	17	6	4
	39	4	355	333	15	5	1	196	186	6	4	1
	34	4	370	342	23	5	1	97	89	5	2	—
	29	2	156	107	31	17	1	113	79	14	18	2
	6.5	7.8	8.2	8.5	7.2	4.6	6.8	7.6	7.8	7.2	3.7	5.5
	1,927	29	7,175	6,047	585	518	26	6,896	5,601	368	885	43
	118	4	221	92	64	60	5	285	117	40	115	13
	420	3	644	381	92	167	4	939	515	67	350	7
	409	3	825	618	86	117	4	1,057	774	57	218	7
	490	7	2,424	2,107	217	95	6	2,600	2,312	155	124	9
	246	4	1,150	1,067	42	39	3	901	839	18	40	3
	134	6	1,071	1,010	45	15	2	629	601	15	11	2
	54	1	483	461	12	9	1	307	294	5	8	—
	33	1	255	242	8	5	—	100	95	2	3	—
	24	—	102	70	20	11	1	79	54	9	15	1
	7.0	8.3	8.5	8.8	7.4	5.5	6.5	7.9	8.2	7.2	4.7	5.2

ber of years of school completed for each class was: native white 8.8; foreign-born white 7.3; Negro 5.7; and other races, 6.8. In the individual urban-rural-by-sex groups, these same rankings are found with one exception. In the urban population, both male and female, the median for "other races" was higher than for foreign-born whites. The reason for this is undoubtedly that the other races in urban areas are almost wholly Orientals with very few

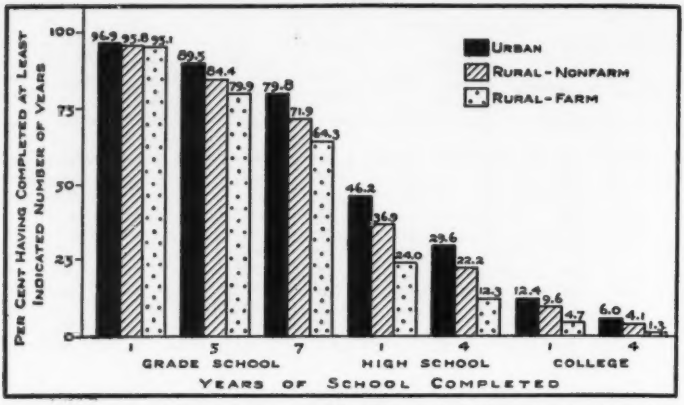

Fig. 1. Per cent of persons 25 years old and over who had completed at least the indicated number of years of school, for United States, urban and rural: 1940. (Standardized for sex and race-nativity. Base is number of persons reporting education.)

Indians. (Mexicans are classed as white.) Medians standardized for urban-rural residence and for sex are unchanged for the two white groups but are increased from 5.7 to 5.9 for Negroes and from 6.8 to 7.4 for other races. These increases reflect mainly the fact that the nonwhites are more concentrated in rural areas than the population as a whole.

Figure 2 shows the cumulative standardized per cent distribution by years of school completed for race-nativity classes. The standardization is for urban-rural residence and sex. A relatively high percentage of the urban foreign-born whites had not completed a single year of school—11.8 per cent of all males and 14.0 per cent of all females reporting education. There is some evidence, however, of possible under-reporting of the education of the foreign-born whites, perhaps of schooling received abroad.

Sex Differences. Sex differences were generally less than those among urban-rural areas or among race-nativity groups. They were also less consistent. For the country as a whole, the median number of years of school completed was 8.3 for males and 8.5 for

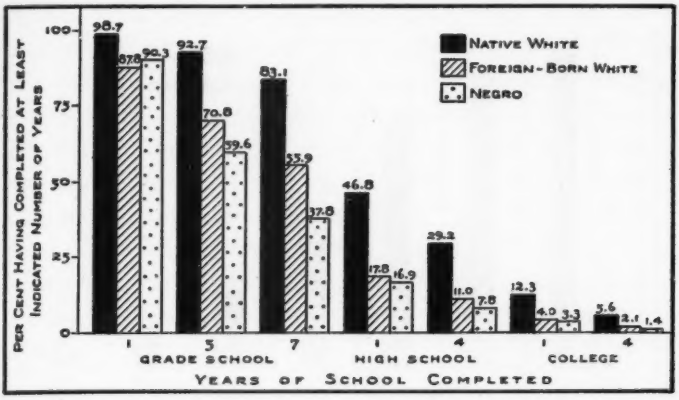

Fig. 2. Per cent of persons 25 years old and over who had completed at least the indicated number of years of school, for race-nativity classes, for the United States: 1940. (Standardized for sex and urban-rural residence. Base is number of persons reporting education.)

females. It would seem, however, that although a larger proportion of men than of women dropped out of school before completing high school, a greater proportion of men than of women who graduated from high school went on to college, and a greater proportion of men than of women who entered college completed their college training.

The median for females was higher than that for males among native whites and among Negroes, regardless of type of residence. Differences were particularly great for Negroes. Medians for foreign-born white males and females were about the same in each of three residence areas. In urban areas the average male in the "other races" group had less formal education than the average female, but in the rural-nonfarm and rural-farm areas the reverse was true.

Standardization for urban-rural residence and for race-nativity composition does not change in the first decimal place the medians for all males and all females aged 25 and over. Standardized cumulative percentage distributions are presented in Figure 3.

Geographic Differences. Table 2 indicates that the Pacific Divi-

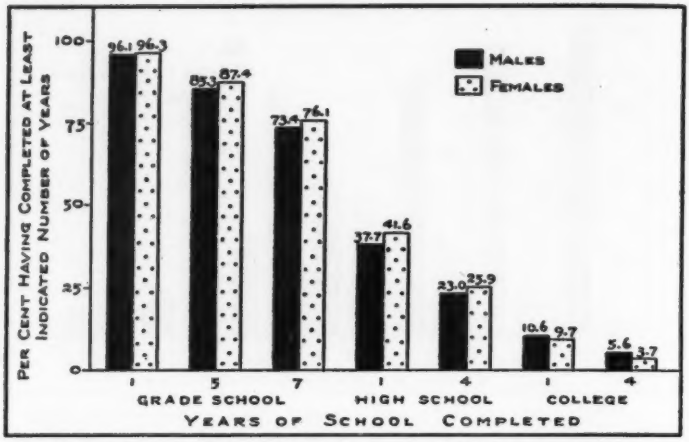

Fig. 3. Per cent of males and of females 25 years old and over who had completed at least the indicated number of years of school, for the United States: 1940. (Standardized for urban-rural residence and race-nativity. Base is number of persons reporting education.)

sion had the highest median number of years of school completed, the highest proportion of college graduates, and the lowest proportion of persons who had completed less than five years of school. On the basis of median number of years completed, the Mountain Division ranked next even though it contained one State, New Mexico, with a rather low median—probably due to its large population of Mexican stock. The four Northern Divisions ranked next and were followed by the three Southern Divisions.

To answer such questions as, "Is the South's low level of educational attainment due to its high proportion of Negroes or do Negroes rank at or near the bottom among the races because of their concentration in the South?" one must examine the educational data for geographic areas by race-nativity and urban-rural residence. Some statistics of this character are summarized in Table 3 in the form of median years of school completed. The distributions on which these medians are based are presented in the Second Series Population Bulletins.

Urban-Rural Differences by States. First we may see whether the urban-rural differences found in the United States as a whole existed in specific areas. Among native whites and Negroes in practically every State the urban population had received more schooling than the rural-nonfarm and the rural-nonfarm in turn more than the rural-farm. The spread between the urban and the rural-nonfarm population in education was usually greater than the spread between the rural-nonfarm and the rural-farm population. Urban native whites averaged from a fraction of a year to two years more schooling than rural-farm native whites in the Northeast and East North Central States, from about a year and a half to three years more in the West North Central States and the West, and up to four years more in the South. (Differences according to residence were less than two years in the border States but from two to four years in the deep South.) Although there is no doubt about the existence of pronounced variations in education according to residence, it is possible that for persons 25 years old and over the observed differences among urban-rural classes are exaggerated somewhat by selective migration of the better educated farm youth to cities.

Just as in the country at large, differences in education among urban-rural classes were generally small for the foreign-born white population of each of the States with appreciable numbers of foreign-born whites. Except in Arizona, New Mexico, and Texas, where the foreign born were mostly Mexicans, residence differences in median years of school completed were about a year or less. In general, the rural-nonfarm foreign-born whites ranked highest in the New England, Middle Atlantic, and East North Central States, whereas in the West North Central, Mountain, and Pacific States, the urban residents were somewhat better educated. In most of the Northern and Western States, as in the country as a whole, the foreign-born white population in rural-nonfarm areas had markedly larger proportions of Northern and Western European

Table 2. Persons 25 years old and over, by years of school completed, for the United States by divisions and States, 1940. (Population in thousands.)

Division and State	Persons 25 Years Old and Over	No School Years Completed	Grade School			High School		College		Not Reported	Median School Years Completed
			1 to 4 Years	5 and 6 Years	7 and 8 Years	1 to 3 Years	4 Years	1 to 3 Years	4 Years or More		
United States	74,776	2,800	7,305	8,515	25,858	11,182	10,552	4,075	3,407	1,042	8.4
New England											
Maine	481	10	25	37	171	96	96	25	16	5	8.9
New Hampshire	294	7	17	24	116	48	49	16	13	4	8.7
Vermont	205	3	9	15	81	38	37	11	8	3	8.8
Massachusetts	2,621	107	157	221	802	485	524	130	143	52	9.0
Rhode Island	424	22	36	51	157	64	55	14	19	5	8.3
Connecticut	1,031	48	68	87	410	142	157	46	50	24	8.5
Middle Atlantic											
New York	8,431	469	551	693	3,343	1,249	1,125	342	462	198	8.4
New Jersey	2,533	110	195	269	984	351	340	102	127	56	8.4
Pennsylvania	5,638	229	467	710	2,208	763	722	224	235	81	8.2
East North Central											
Ohio	4,104	82	262	448	1,552	671	659	203	181	45	8.6
Indiana	2,004	26	129	198	832	306	311	103	76	23	8.5
Illinois	4,828	132	330	434	2,021	705	688	258	216	44	8.5
Michigan	3,007	72	233	296	1,082	557	456	158	121	31	8.6
Wisconsin	1,809	30	139	198	799	221	228	102	70	21	8.3
West North Central											
Minnesota	1,600	23	96	142	723	203	225	106	67	15	8.5
Iowa	1,471	8	52	107	643	221	258	101	61	20	8.7
Missouri	2,260	43	190	250	969	285	288	121	88	26	8.3
North Dakota	328	7	28	33	148	35	35	26	12	4	8.3
South Dakota	343	4	21	30	157	44	44	28	13	3	8.3
Delaware	158	5	15	21	49	27	22	7	8	4	8.5
Maryland	1,055	30	132	188	326	136	122	44	50	26	8.0
District of Columbia	431	7	28	41	108	65	87	41	47	6	10.2

Missouri	2,260	43	190	250	969	285	288	121	88	26	8.3
North Dakota	328	7	28	33	148	35	35	26	12	4	8.3
South Dakota	345	4	21	30	157	44	44	28	13	3	8.5
Delaware	158	5	15	21	49	27	22	7	8	4	8.5
Maryland	1,055	30	132	188	326	136	122	44	50	26	8.0
District of Columbia	431	7	28	41	108	65	87	41	47	5	10.3
Virginia	1,376	74	245	245	324	178	151	82	61	17	7.7
West Virginia	928	34	119	162	349	89	85	47	31	11	7.8
North Carolina	1,650	95	338	309	345	226	153	89	67	27	7.4
South Carolina	841	66	226	147	121	118	73	40	39	11	6.7
Georgia	1,533	100	362	280	300	211	141	73	51	17	7.1
Florida	1,082	43	158	151	270	159	164	66	53	19	8.3
East South Central											
Kentucky	1,441	59	232	229	541	140	120	60	42	17	7.7
Tennessee	1,498	62	262	269	434	183	151	72	46	19	7.7
Alabama	1,355	91	300	263	292	177	118	56	39	19	7.1
Mississippi	1,044	69	246	184	230	132	89	45	31	17	7.1
West South Central											
Arkansas	968	37	187	178	287	123	84	39	22	12	7.5
Louisiana	1,205	154	275	203	206	144	118	51	42	10	6.6
Oklahoma	1,213	30	134	162	400	178	155	81	57	16	8.4
Texas	3,414	179	462	499	713	695	450	234	150	30	8.5
Mountain											
Montana	315	5	19	25	126	47	49	27	15	3	8.7
Idaho	275	2	12	18	106	50	44	27	12	4	8.9
Wyoming	137	3	7	10	47	25	25	12	7	1	9.2
Colorado	638	15	42	51	216	104	114	51	38	8	8.9
New Mexico	247	26	41	28	57	32	30	17	11	4	7.9
Arizona	253	23	27	25	65	37	38	19	16	3	8.6
Utah	268	4	11	16	79	57	53	29	16	3	10.2
Nevada	67	2	4	4	20	12	13	6	4	2	9.6
Pacific											
Washington	1,074	13	50	73	387	183	212	86	59	9	9.1
Oregon	676	7	28	42	252	117	126	58	37	8	9.1
California	4,421	111	247	307	1,299	779	965	371	296	47	9.9

Table 3. Median years of school completed for persons 25 years old and over, by race-nativity for the United States, urban and rural, by States, 1940. (Median not shown where base is less than 100.)

Division and State	Urban				Rural-Nonfarm				Rural-Farm			
	All Classes	Native White	Foreign-born White	Negro	All Classes	Native White	Foreign-born White	Negro	All Classes	Native White	Foreign-born White	Negro
United States	8.7	9.6	7.4	6.8	8.4	8.6	7.3	5.0	7.7	8.0	7.2	4.1
New England												
Maine	9.1	10.2	7.4	8.2	9.0	9.5	7.8	7.6	8.7	8.8	7.7	—
New Hampshire	8.6	9.3	7.3	8.1	8.9	9.2	7.7	—	8.7	8.9	7.6	—
Vermont	9.5	10.3	7.8	8.1	8.8	9.0	7.9	—	8.5	8.6	7.7	—
Massachusetts	9.0	10.7	7.4	8.2	9.3	10.4	7.5	6.9	8.6	9.8	6.5	2.2
Rhode Island	8.3	8.8	6.8	7.6	8.3	8.6	7.0	7.4	8.2	8.6	6.3	—
Connecticut	8.4	9.0	7.0	7.5	8.7	9.6	7.4	7.9	8.3	8.8	7.0	7.7
Middle Atlantic												
New York	8.4	9.1	7.4	7.8	8.7	8.9	7.7	7.2	8.3	8.4	7.3	7.0
New Jersey	8.4	8.9	7.1	7.2	8.4	8.7	7.5	6.7	7.9	8.3	7.1	5.9
Pennsylvania	8.4	8.8	6.1	7.1	8.1	8.3	5.2	6.6	8.0	8.1	5.7	6.5
East North Central												
Ohio	8.7	9.4	6.9	7.4	8.5	8.6	6.9	6.9	8.2	8.3	6.8	7.2
Indiana	8.7	8.9	7.1	7.6	8.5	8.5	7.6	7.3	8.2	8.2	7.2	7.5
Illinois	8.6	9.2	7.5	7.7	8.3	8.4	7.2	6.6	8.1	8.2	7.6	6.5
Michigan	8.8	9.8	7.6	7.6	8.6	8.8	7.5	7.0	8.1	8.3	6.5	7.4
Wisconsin	8.6	8.9	7.3	7.6	8.4	8.5	7.4	7.5	7.9	8.0	7.1	7.1
West North Central												
Minnesota	8.9	10.0	7.7	8.4	8.4	8.7	7.4	7.8	8.0	8.1	7.3	—
Iowa	9.6	10.0	7.8	8.0	8.7	8.8	7.7	7.1	8.4	8.4	7.8	7.7
Missouri	8.6	8.8	7.5	7.4	8.3	8.3	7.7	6.5	7.9	7.9	7.4	4.9
North Dakota	9.8	11.0	7.8	—	8.4	8.8	7.5	—	7.9	8.1	7.3	—
South Dakota	10.0	10.6	7.9	8.6	8.6	8.8	7.6	—	8.1	8.2	7.6	—
Maryland	8.0	8.5	6.4	6.1	8.2	8.5	8.0	5.6	7.4	7.7	7.6	4.7
District of Columbia	10.3	12.1	8.3	7.6	—	—	—	—	—	—	—	—
Virginia	8.7	10.0	8.3	5.9	7.6	8.3	8.7	4.8	6.6	7.3	7.7	4.1

Iowa	9.6	10.0	7.8	8.0	8.7	8.8	7.7	7.1	8.4	8.4	7.6	7.7
Missouri	8.6	8.8	7.5	7.4	8.3	8.3	7.7	6.5	7.9	7.9	7.4	4.9
North Dakota	9.8	11.0	7.8	—	8.4	8.8	7.5	—	7.9	8.1	7.3	—
South Dakota	10.0	10.6	7.9	8.6	8.6	8.8	7.6	—	8.1	8.2	7.6	—
Maryland	8.0	8.5	6.4	6.1	8.2	8.5	8.0	5.6	7.4	7.7	7.6	4.7
District of Columbia	10.3	12.1	8.3	7.6	—	—	—	—	—	—	—	—
Virginia	8.7	10.0	8.3	5.9	7.6	8.3	8.7	4.8	6.6	7.3	7.7	4.1
West Virginia	8.7	8.9	6.9	7.4	7.6	7.7	5.1	6.1	7.3	7.3	5.2	5.7
North Carolina	8.6	10.3	10.5	5.8	7.6	8.2	11.7	5.0	6.6	7.2	8.8	4.4
South Carolina	8.7	11.3	8.9	4.8	6.9	8.2	10.3	3.8	5.5	7.7	9.7	3.5
Georgia	8.1	10.0	8.8	5.1	7.5	8.6	10.1	4.0	6.0	7.2	9.2	3.5
Florida	8.9	11.0	8.2	5.8	7.9	8.7	8.6	4.3	7.1	7.8	8.1	3.8
East South Central												
Kentucky	8.4	8.6	7.8	6.7	7.7	7.8	7.8	5.9	7.2	7.2	7.7	5.2
Tennessee	8.4	9.4	8.4	6.2	7.8	8.0	8.9	5.4	7.0	7.3	7.2	4.9
Alabama	8.3	10.3	8.3	5.6	7.3	8.2	8.0	4.5	6.1	7.1	7.6	3.7
Mississippi	8.7	11.7	8.4	5.8	8.0	9.9	8.5	5.0	6.2	8.1	5.4	4.3
West South Central												
Arkansas	8.9	10.4	8.4	6.3	7.8	8.3	7.8	5.3	6.9	7.4	6.8	4.6
Louisiana	7.9	9.1	7.3	5.2	6.5	8.1	6.1	3.5	4.5	6.3	2.7	2.8
Oklahoma	9.9	10.4	8.3	7.6	8.2	8.3	7.2	6.3	7.7	7.7	7.1	6.0
Texas	9.5	10.6	4.8	6.8	8.7	9.3	2.9	5.7	7.5	8.0	2.4	5.3
Mountain												
Montana	9.6	10.7	7.8	8.0	8.7	9.1	7.7	—	8.3	8.5	7.7	—
Idaho	10.5	10.8	8.2	7.5	8.9	9.0	7.9	7.0	8.6	8.7	7.8	7.4
Wyoming	10.3	10.9	7.6	7.9	9.3	10.0	7.4	7.5	8.6	8.7	7.5	—
Colorado	9.9	10.5	7.6	8.5	8.7	8.9	7.0	7.5	8.3	8.5	7.2	7.7
New Mexico	9.3	9.9	6.4	7.4	7.5	7.8	3.8	7.1	6.7	7.2	3.2	6.2
Arizona	9.6	10.9	6.5	7.6	8.6	9.2	4.8	7.3	7.2	8.5	3.9	6.6
Utah	10.8	11.5	8.0	8.4	9.7	10.1	7.6	—	9.0	9.4	7.5	—
Nevada	10.5	11.3	7.9	7.6	9.5	10.5	7.5	8.2	8.4	9.0	7.4	—
Pacific												
Washington	10.1	11.0	8.2	8.2	8.9	9.4	8.0	7.9	8.4	8.6	7.8	7.6
Oregon	10.2	10.8	8.2	8.4	8.9	9.1	8.1	8.0	8.5	8.6	7.9	—
California	10.5	11.4	8.0	8.5	8.9	9.6	7.5	7.3	8.3	8.8	6.9	6.8

stock than the urban areas. In the Dakotas, the Mountain States, and California the reverse was true. This contrast may explain part of the above-mentioned regional variations in education according to residence. Immigrants from Southern and Eastern Europe and Latin America probably did not have as many years of schooling as the white immigrants from other regions.

Educational Status of Negroes by States. The relatively low educational attainment of the Negro population is most marked in the South but exists to some extent in other regions. The native-white median was less than three years above the Negro median in most residence areas of Northern, Western, and border States. In the deep South, on the other hand, the difference was greater than three years in most States. It was 6.5 years in urban South Carolina. We need have no hesitancy in ascribing a major part of these regional variations to a wider spread between educational opportunities for whites and Negroes in the South than in the North or West. In no urban, rural-nonfarm, or rural-farm area of any State did the native-white population fail to average more formal education than the Negro, however.

In comparing the education of Southern Negroes with that of those living in the North and West, it is desirable to confine our attention to the urban areas since few Negroes outside the South are found in rural areas. The median of 7.1 years of school completed among Negroes in urban Pennsylvania was lower than the median in any other Northern or Western State, there being a range up to about 8.5 years. In the District of Columbia and in Oklahoma, the median for urban Negroes was 7.6 years, and it was 7.4 in West Virginia. Elsewhere in the South it was below seven years, ranging down to 4.8 years in South Carolina. It is probably true that part of the superior education of Negroes living in the North and West is attributable to the northward migration of some of the better educated Negro youth from the South, but at present we have few quantitative data on this selective process.

The educational status of Negroes was, of course, very low in the rural South. In rural-nonfarm areas, the average Negro had completed as much as six years of elementary school only in Oklahoma and West Virginia. The median was below five years in the rural-farm areas of all Southern States except Oklahoma, West Virginia, Texas, Kentucky, and Delaware. Louisiana rural-farm Negroes 25 years old and over averaged less than three years of elementary school.

Educational Status of the Foreign-Born Whites by States. The highest grade of school completed by foreign-born whites was lower on the average than that completed by native whites in every residence area except in a few Southern States where the foreign-born whites were numerically unimportant. The differences seem to have been somewhat smaller in rural than in urban areas. They were only a fraction of a year in the rural-farm areas of the West North Central States, Wisconsin, Montana, and Idaho. Here many of the foreign-born were from Germany and Scandinavia, and many of the native whites were the children of immigrants from these countries. In the urban populations of practically all Northern and Western States, the educational attainment of foreign-born whites was less than that of Negroes.

Sex Differences by States. As in the United States as a whole, differences within States were generally small between the educational attainment of males and of females. Usually, medians were higher for women. In the native-white population, women had more education than men on the average in practically every urban-rural area of every State, but the difference was generally less than two years. The situation in the foreign-born white population was less simple. In the large foreign-born urban populations of the Middle Atlantic and North Central States, males were slightly better educated. The average male had decidedly more education in the nonfarm areas of Arizona and New Mexico, where many of the foreign-born whites were born in Mexico. Elsewhere, females

had slightly more schooling. Much more meaningful differentials would probably be found if years of school completed were shown by country of birth for the foreign born. Negro women were better educated than Negro men, particularly in the rural South where the need or opportunity for employment was probably greater for Negro boys than for Negro girls.

State Differences Within Groups. The regional patterns described above among the entire adult populations of States become much less clear-cut if we compare educational attainment within a particular group by States. The urban native-white population in the Southern States did not compare at all unfavorably with that in the Northern and Western States. Both the highest and the lowest medians were in the South, and it is striking that the highest median (over three years of high school) was in Mississippi in the deep South and the lowest median (less than a full year of high school) was in Maryland, a border State. In the rural-nonfarm native-white population, and even more in the rural-farm, Southern States did not make so good a relative showing; nevertheless, in these same areas the medians in some Southern States were higher than the medians in some Northern and Western States. Educational differentials by States for the foreign-born white population were even less uniform. Regional variations in the educational attainment of Negroes have already been discussed.

It is possible that, with allowance for differences in race-nativity and residence, State differences in medians may reflect largely the age composition of the adult population. Then, other things being equal, a State with a young population would have a relatively well educated population.

Conclusion

We have seen that there are rather wide variations in educational status among certain types of groups and areas in the United States. Within a particular group in a particular area there is also a range

among individuals, which is not brought out by the median years of school completed. The distribution of an adult population in an area by residence, race, age, and, to a lesser extent, sex, affects but does not determine its educational level. Standardized rates holding these factors constant would indicate the importance of other factors associated with inter-area differentials. Measures of some of these factors are undoubtedly available. It is obvious that differences in economic status must account for a large part of the inter-group and intra-group differentials, but local and individual peculiarities (some of which are listed in Appendix A) also play a part.

Familiarity with the effects of internal migration upon the educational level in both the area of destination and the area of origin would direct the interests of a citizenry beyond the school system of its own locality. Much research remains to be conducted upon these effects, but a good beginning may be made on the basis of forthcoming census tabulations. This problem has implications for the instruction of youth as well as for adult education, whereas the existence of differentials among the foreign-born according to country of birth is relevant chiefly to programs of adult education. Here again a census tabulation, now fairly well advanced, will provide useful information.

A much more satisfying analysis of the data on years of school completed can also be made when the Fourth Series Population Bulletins, giving education by age, are published. Although these contain data only for such large areas as States, urban and rural, and cities of 50,000 or more, the tables of age-specific rates for such areas will furnish a means of indirect standardization for smaller areas with similar characteristics. Many valuable data on years of school completed from the 1940 Census remain to be presented but much can be done with what is already available, particularly on a descriptive level for small areas. When some of the other publications become available, it will be possible to undertake a more

thorough analysis of the relationships between education and other factors.

Appendix A.—Definitions and Explanations

Definition of "Last Year of School Completed." The instructions to the enumerator read "Enter . . . for each person, the last full grade of school completed, that is, the highest full grade that the person has successfully finished or from which he has been graduated. Do not include half years or grades that were not finished." This question referred only to education obtained in public, private, or parochial schools, colleges, or universities. Education obtained at vocational schools was not considered, unless such a school or college was a part of the regular school system. For a person still in school, the last full grade completed was the grade preceding the one in which he was then enrolled. For a person who completed his formal education in an ungraded school or in a foreign country, the approximate equivalent grade in the American school system was to be entered. Also for a person who obtained his entire education in night school, the approximate equivalent grade completed was called for.

Limitations of the Census Index of Educational Status. It seems desirable to state here some reservations that should be made in interpreting the foregoing data; the fact that age is not controlled beyond a restriction to those 25 years old and over has already been noted.

The census definition of years of school completed has been given, and it has been remarked that the measure of formal education so defined is a valuable index of social-economic status. It is evident, however, that the same number of school years completed in two different States will not represent exactly the same thoroughness of training or the completion of the same curriculum since the educational standards of the two States may differ.[5] The number of years of school completed by an individual is the resultant of such factors as his innate intelligence, his effort, and the economic circumstances of his family. It is also influenced by opportunities for employment in the community, the attractiveness of the local curriculum, and the school facilities in general. These last are largely determined by the economic resources of the area but are also affected by local or State govern-

[5] In a few of the Southern States there are only seven years of elementary school. For the sake of uniformity, however, the first year of high school in such areas has been treated as the ninth rather than the eighth year of school. It is felt that this convention leads to more comparable medians for the several States.

mental policy. Despite this lack of constancy in what the measure ultimately represents, special studies[6] have found very high correlations between the number of years of school completed and demographic characteristics like fertility and age at marriage and social-economic characteristics like broad occupational group, equivalent rent, and income. It is thought that most other demographic, social, and psychological characteristics will also be more profitably analyzed when the factor of education is controlled. Furthermore, education may be held constant for many groups of adults to whom some other social-economic index would not be applicable.

It must also be considered that practically all of the persons in the age group 25 years old and over completed their education some time in the past, and hence their amount of schooling does not reflect the facilities existing in their communities at present. Furthermore, many present residents of an area were reared and educated elsewhere. Prominent examples are the many Negroes who have migrated from the rural South to the urban North and the Dust Bowl people who have settled on the Pacific Coast.

Comparability with Literacy Statistics. Many persons will be interested in knowing whether the statistics on years of school completed may be used in any way to continue the time series on illiteracy that extends from 1870 to 1930. The answer is mainly in the negative since the completion of no particular grade of school corresponds to the attainment of a state of literacy. Ability to read and write is a less clear-cut concept than the completion of a given number of years of school, and even if literacy could be precisely defined the grade in which it was acquired would depend both on the individual and the school system. Some few quite literate individuals, of course, never had any formal schooling.

Comparison of the 1930 figures on illiteracy with the 1940 figures on years of school completed confirms this reasoning. The 1930 proportion of illiterates among persons 25 years old and over generally lies between the proportion of persons of this age in 1940 who had not completed a full year of school and the proportion who had completed less than five years. (Separate statistics on the number of persons completing one, two, three, or four years are

[6] Karpinos, Bernard D. and Kiser, Clyde V.: The Differential Fertility and Potential Rates of Growth of Various Income and Educational Classes of Urban Populations in the United States. The Milbank Memorial Fund *Quarterly*, October, 1939, xvii, No. 4, pp. 367-391.

Hutchinson, E. P.: Education and Intramarital Fertility in Stockholm. *Ibid.* July, 1936, xiv, No. 3, pp. 285-301.

Population Index, January, 1940, 6, No. 1, pp. 72-74.

not yet available.) More important, when the codistributions of the 1930 illiteracy rate and either 1940 education index are plotted for States, high correlations are indicated, but a fair amount of scatter about the regression lines is also obvious. This scatter shows that among the States there is not a constant relationship between the percentage of illiteracy and either the percentage completing no years of school or the percentage completing less than five years of school.

Appendix B.—Tabulations Available or Planned

The following outline summarizes the material now available, classified as tabulated and published or as tabulated but not intended to be published, and also material in process or included in plans that have a reasonable certainty of being carried out. The statistics so far available on education give abridged detail on the number of years of school completed and are limited to persons 25 years old and over without any further classification by age. Tabulations now under way for the larger areas give for five-year age groups from 25 to 74 the number of persons who have completed each year of school. From the same count of the cards for individuals, we shall also obtain distributions by years of school completed for each single year of age from 5 to 24 classified according to whether or not attending school. These data for younger persons will enable educators to gauge much more exactly than ever before the extent of retardation or acceleration in the school population of a given area.

DATA ON LAST YEAR OF SCHOOL COMPLETED FROM THE 1940 CENSUS

1. *PUBLISHED*

Population covered: All persons 25 years old and over.
Categories of school years completed: 0, 1-4, 5-6, 7-8, H1-H3, H4, C1-C3, C4 and over.

Publication	*Areas*	*Cross-Classified Characteristics*
A. Release Series P-6	States by urban, rural-nonfarm, and rural-farm areas	None
B. Release P-10, No. 8	1. U. S. by urban, rural-nonfarm, and rural-farm areas	Sex by race (native white, foreign-born white, Negro, other races)

	2. Regions, divisions, and States	None
C. Second Series Population Bulletins	1. States by urban, rural-nonfarm, and rural-farm areas; cities of 100,000 or more; large metropolitan districts	Sex by race (native white, foreign-born white, Negro, other races)
	2. Counties; urban places of 10,000-100,000	Sex
	3. Rural-nonfarm and rural-farm areas of counties; urban places of 2,500-10,000	None

II. *AVAILABLE*

Population covered: All persons 25 years old and over.
Categories of school years completed: 0, 1-4, 5-6, 7-8, H1-H3, H4, C1-C3, C4 and over.

Areas	*Cross-Classified Characteristics*
Tracted areas by tracts, untracted cities of 100,000 or more by wards, each urban place of 2,500-100,000 separately; rural-nonfarm and rural-farm areas of counties	Sex by race (native white, foreign-born white, Negro, other races)

III. *IN PREPARATION*

To be published in Fourth Series Population Bulletins.
Areas: Each city of 50,000 or more; balance of each State by urban, rural-nonfarm, and rural-farm areas.
Categories of school years completed: Single years from 0 to C5 and over.

Population Covered	*Cross-Classified Characteristics*
	N.B. Cross-classification by color is complete in the tabulations but will be published only for selected areas.
A. Persons 5 to 24 years of age	Sex by age (single years) by school attendance

B. Persons 25 years of age and over	Sex by age (5-year groups to 74 years)

IV. *OTHER TABULATIONS PLANNED OR IN PROCESS*

Subject	*Data*
A. Migration	Last year of school completed (under 5, 5-6, 7-8, H1-H3, H4, C1-C3, C4 and over) by sex by residence in 1935 for persons 25 to 34 years old.
B. White population by nativity and parentage (sample tabulation)	Last year of school completed (0, 1-4, 5-6, 7-8, H1-H3, H4, C1-C3, C4 and over) by sex by age (under 25, 25-34, 35-44, 45-54, 55-64, 65 and over) by nativity and parentage, native of native parentage, native of foreign or mixed parentage, foreign-born).
C. Male population, 18 to 44 (sample tabulation)	Last year of school completed (under 4, 4-8, H1-H3, H4, C1-C3, C4 and over) by age (18-29 by single years, 30-34, 35-39, 40-44) by relationship and marital status (head; nonhead, single; nonhead, other) by broad occupational group.
D. Fertility (sample tabulation)	Contents under consideration
E. Families (sample tabulation)	Contents under consideration

MEDICAL EVALUATION OF NUTRITIONAL STATUS[1]

XIII. THE EXPERIMENTAL ERROR OF DETERMINATIONS OF ASCORBIC ACID IN PLASMA BY MICROMETHOD OF MINDLIN AND BUTLER

GILBERT W. BEEBE

INCREASING interest in the ascorbic acid content of blood plasma has raised the question of the accuracy of single determinations obtained according to the widely employed colorimetric procedures of Mindlin and Butler (1). A previous paper (2) from the Medical Evaluation of Nutritional Status Study, undertaken jointly by the New York City Department of Health, the United States Public Health Service, Cornell University Medical College, and the Milbank Memorial Fund, discussed the sources of experimental error in the *macromethod* of Mindlin and Butler and estimated their aggregate effect upon a single determination of the ascorbic acid content of plasma. The present report does this for the *micromethod*. The observations were made in the Study laboratories in order to provide a basis for estimating the reliability of a single determination of the ascorbic acid content of plasma. The possibility of *systematic* error is discussed briefly at the end of the paper.

Both the micromethod and the macromethod are based upon the same principles of physical chemistry, and these are discussed by Mindlin and Butler in their original communication (1). The reduction of 2.6 dichlorophenol-indophenol by ascorbic acid is objectively measured by means of the photoelectric micro-colorimeter.

[1] This paper is the thirteenth of a series from a cooperative investigation by the New York City Department of Health; the Division of Public Health Methods, National Institute of Health, United States Public Health Service; the Cornell University Medical College, Department of Public Health and Preventive Medicine and Department of Pediatrics; and the Milbank Memorial Fund.

The cooperating agencies have been assisted in carrying out this investigation by the Work Projects Administration for the City of New York, Official Project No. 65-1-97-21 W.P. 24, "Medical Evaluation of Nutritional Status."

The ascorbic acid content of a sample of plasma may be calculated from the expression

$$(1) \quad C = K (\log G_s - \log G_b)$$

where G_s is the galvanometer reading on the dye-acetate blank plus plasma filtrate, and G_b is a parallel reading on the dye-acetate blank. The factor K is the ratio of a standard concentration of ascorbic acid in metaphosphoric acid to the difference between the logs of the galvanometer readings on the dye blank plus the standard solution and on the dye blank. It is obtained by solving equation (1) when G_s is the galvanometer reading on the dye-acetate blank plus the standard solution of strength C.

For purposes of statistical analysis it is convenient to rewrite equation (1) as

$$(2) \quad C_p = \frac{C_s(L_b - L_p)}{(L_b - L_s)} = t = \frac{X_1 \cdot X_2}{X_3}$$

where

$C_p = t$ = estimated ascorbic acid content of the plasma, *e.g.*, .75 mg. per cent;

$C_s = X_1$ = standard concentration of ascorbic acid in metaphosphoric acid added to dye-acetate blank, and stated as mg. per cent;

$(L_b - L_p) = X_2$ = difference between logs of galvanometer readings on dye blank and dye blank plus plasma filtrate, where L_b may be the mean of several independent readings, and any L reading is $\log \left(\frac{100}{G}\right)$ or $2 - \log G$; and

$(L_b - L_s) = X_3$ = difference between logs of galvanometer readings on the dye blank and on the dye blank plus the standard solution, and where $(L_b - L_s)$ may be the difference between the means of several independent readings. An L reading, again, is $2 - \log G$.

Each element in the above series is subject to one or more kinds of experimental error. If the magnitude of each can be estimated, the resulting information can be combined so as to provide an estimate of the error of a single plasma determination.

Sources of Experimental Error and Their Estimation

The major opportunities for error arise from

(1) the operations involved in preparing the solutions, especially the standard ascorbic acid solutions;

(2) the manipulation of the colorimeter and the galvanometer;

(3) whatever physical and chemical differences or changes there may be in the properties of the dye-stocks, dye solutions, etc.;

(4) the arbitrary standard concentration of ascorbic acid employed in finding K, as shown by Wiehl and Kantorovitz (2).

From multiple, independent galvanometer readings (L_b, L_s, and L_p in 2-log form) on the same day with a given dye-acetate solution, estimates of the error of each of these three factors and of the differences ($L_b - L_p$) and ($L_b - L_s$) may be found as the average within-the-day variances computed from a considerable number of replicate experiments done over a period of time, with different dye-stocks, and with many samples of plasma filtrate. The error made in preparing standard ascorbic acid solutions (error of C_s, or S_1^2) must, however, be estimated indirectly. Wiehl and Kantorovitz (2) showed that the error of K among days, for a given C_s level, should be calculable from the formula for the variance of a ratio as

$$(3)\quad S_K^2 = S^2_{\left(\frac{X_1}{X_3}\right)} = \left(\frac{\overline{X}_1}{\overline{X}_3}\right)^2 \left[\frac{S_1^2}{\overline{X}_1^2} + \frac{S_3^2}{\overline{X}_3^2} - 2r\frac{S_1 S_3}{\overline{X}_1 \overline{X}_3}\right]$$

where the variances are the error variances about the means $\overline{X}_1$ (the value of C_s, and $\overline{X}_3$ (the average value of $L_b - L_s$). The term involving the correlation coefficient vanishes under the assumption that the error made in preparing C_s solutions is independent of the error of $L_b - L_s$. It is further assumed that the error of K among days depends upon the error of C_s and upon the experimental error of the difference ($L_b - L_s$), the latter being best approximated as the within-the-day variance of replications. The

among-days variance of $(L_b - L_a)$ is increased by the errors of C_a and is thus a poor estimate of S_t^2. Then the error of C_a is found by solving equation (3), shorn of the third term within the brackets, for S_t^2. Should it be found that the error of C_a depends upon the C_a level itself, a set of estimates could be obtained which would be appropriate to the different C_a levels. Finally, from estimated values of $\overline{X}_1$, $\overline{X}_2$, $\overline{X}_3$, S_1^2, S_2^2, and S_3^2, and from known formulas for the variance of a product and of a ratio (3), the error variance of C_p may be computed from the formula

$$(4)\quad S_{C_p}^2 = S_t^2 = \left(\frac{\overline{X}_1 \cdot \overline{X}_2}{\overline{X}_3}\right)^2 \left[\frac{S_1^2}{\overline{X}_1^2} + \frac{S_2^2}{\overline{X}_2^2} + \frac{S_3^2}{\overline{X}_3^2} + \frac{S_1^2 S_2^2}{\overline{X}_1^2 \overline{X}_2^2} - 2rS_3\sqrt{S_1^2\overline{X}_2^2 + S_2^2\overline{X}_1^2 + S_1^2 S_2^2}\right]$$

where r is the coefficient of correlation between X_3 and the product $X_1 \cdot X_2$. It can be shown that, for this particular problem, no matter what value r may take within its range $-1 \leq r \leq 1$, the term in which it appears must be negligible in size.

The Laboratory Observations

The Study laboratory provided three sets of observations:

(1) *The first test series.* On each of six days, independent, triplicate readings were made for L_b and also for L_a using separate aliquots of .1, .3, .5, .75, 1.0, 1.5, and 2.0 mg. per cent standard solutions (fresh daily) of ascorbic acid which were added to a single dye-acetate solution which itself was unchanged over the six-day period. Two or three independent observations were also made on six different dye blank plus plasma filtrate samples on two different days.

(2) *The second test series.* On each of five days quadruplicate galvanometer readings were taken for L_b and also for L_a using .1, .3, .5, .75, 1.0, 1.5, and 2.0 mg. per cent standard solutions of ascorbic acid added to a second dye-acetate solution prepared from a second dye-stock. No blood samples were studied.

(3) *The third test series.* On each of five to nine days triplicate

(rarely, duplicate) observations were made on L_b and also on L_s using 1.25 and 1.88 mg. per cent standard solutions of ascorbic acid added to a single dye-acetate solution from a single stock, and for four different dye-stocks. On most days duplicate (rarely, multiple) L_p readings were taken on many dye blank plus plasma filtrate samples.

A. For dye-stock dated 10/10, for 13 plasma samples, and for seven work-days during a nine-day interval.

B. For dye-stock dated 2/19, for 82 plasma samples, and for nine work-days during a fourteen-day interval.

C. For dye-stock dated 3/11, for 68 plasma samples, and for six work-days during a twelve-day interval.

D. For dye-stock dated 4/1, for 51 plasma samples, and for five work-days during a five-day interval.

A small amount of information pertaining to the work of one or two days on each of several different dye-acetate solutions was sacrificed in view of the marked variation among dye-stocks found by Wiehl and Kantorovitz. Only runs of five or more days on a single dye-acetate solution, therefore, are included in the statistical analysis which follows, and each run of observations was first treated as a separate set of data. Throughout the statistical analysis to be described the observations were first processed as single determinations, and account of replication was taken later by dividing the error variances of single readings by the appropriate constants.

Experimental Error of Individual Laboratory Operations

Reading on Dye Blank (L_b). The error of L_b may be gauged from the six independent estimates of variance which appear in Table 1. Each estimate gives the experimental error of a single L_b reading and was found as the within-the-day variance of replicated (usually triplicated) readings. The estimate of 0 for series III-D is derived from only five pairs of duplicates and represents an almost

negligible amount of information. It has been omitted in what follows because the approximate test for homogeneity which was adopted (4) makes use of log S^2 and log 0 is meaningless. As a set the five remaining individual estimates differ only insignificantly ($.50 < P < .70$) and have been combined to yield the average variance of 108.775×10^{-8}* which appears on the total line of the table. For subsequent computations, therefore, 108.775×10^{-8} will serve as the best available estimate of the error variance of L_b. Hence, one-third of this quantity, or 36.258×10^{-8}, is the estimated error of L_b found as the mean of three independent readings upon the same dye-blank.

Table 1. Summary of information on the error of a single galvanometer reading upon a dye blank, in log units.

Series	Degrees of Freedom (n)	Error Variance[1] ($S^2 \times 10^8$)
I	12	68.72
II	15	76.07
III-A	13	121.33
III-B	16	144.81
III-C	10	131.92
III-D	4	0
ALL[2]	66	108.775

[1] Computed as average within-the-day variance for replicated readings, since the much larger variance among days reflects not only the error made in taking a galvanometer reading, but also any changes in the reaction of the dye with time or changes in the calibration of the instruments.
[2] Omitting III-D. The value of S^2 was found as: $\frac{n_1S_1^2+n_2S_2^2+\ldots+n_5S_5^2}{n_1+n_2+\ldots+n_5}$.
For this set of variances $\chi^2=2.86$, and $.70>P>.50$.

Reading on Dye Blank Plus Plasma (L_p). The error of L_p, the reading on the dye blank plus the plasma filtrate, is found almost as readily. In the expectation that the error of L_p might depend upon the concentration of ascorbic acid in the plasma, three levels were recognized. These are: under .50, .50 to .99, and 1.00 or more mg. ascorbic acid per 100 cc. of plasma. Table 2 presents the available information on the magnitude of this error. For series I and III-A it is the within variance for triplicate or quadruplicate readings which is tabled. For the other series the error variance has been estimated as one-half the variance of the difference between

* Powers of 10 are employed to avoid unwieldy numbers. The reader will recall that multiplication by 10^{-2}, for example, amounts to division by 100, or to moving the decimal point two places to the left. Thus 108×10^{-8} is equivalent to .000 001 08.

independent duplicates.[8] At the lowest ascorbic acid level there is evidence of heterogeneity, the value of 726 being well in excess of those of 118 and 117, but the estimates within each of the other two levels are reasonably homogeneous. More important, however, is the absence of any suggestion that the error of L_p depends upon the ascorbic acid level. A weighted average variance of all twelve estimates, therefore, has been computed directly in the usual fashion and appears on the total line of Table 2. The value 246.300×10^{-3} is well above the error variance of 108.775×10^{-3} estimated for single L_p readings. This result is entirely expected, for the handling of micro quantities of plasma in addition to the dye should introduce new errors. Whenever an estimate of the error of a single L_p reading is needed, therefore, use will be made of the figure 246.300×10^{-3}.

Reading on Dye Blank Plus Standard Solution (L_s). In similar fashion Table 3 summarizes the various estimates of the error of a single galvanometer reading on a dye-acetate blank to which a standard concentration of ascorbic acid has been added. Although some of the paired comparisons from series III differ significantly, there is no convincing evidence that the error of L_s depends upon the strength of the ascorbic acid solution added to the dye.[8]

[8] Given a series of duplicate observations on X,

$$X_1', X_2', \ldots X_n' \text{ and } X_1'', X_2'', \ldots X_n'',$$

where $X_i' = X_i + e_i'$ and $X_i'' = X_i + e_i''$,

the difference $d_i = X_i' - X_i'' = e_i' - e_i''$

and the variance of the d's may be written

$$S_d^2 = S_{e'}^2 + S_{e''}^2 - 2rS_{e'}S_{e''}$$

where r is the coefficient of correlation between the errors e′ and e″. Since e′ and e″ may be assumed to be independent when the duplicate observations are independent, and since $S_{e'}^2$ and $S_{e''}^2$ are both equally good estimates of S_e^2, the error of X,

$$S_e^2 = \tfrac{1}{2} S_d^2.$$

[8] The information at each level of ascorbic acid solution was pooled to provide an estimate of error at each of the 9 levels. As standard deviations multiplied by 10^4 these es-

(Continued on page 396)

Series	Degrees of Freedom (n)	Error Variance ($S^2 \times 10^5$)
Plasma Ascorbic Acid Under .50 Mg. Per Cent		
III-A[1]	17	726
III-C[2]	24	118
III-D[2]	22	117
Plasma Ascorbic Acid .50–.99 Mg. Per Cent		
III-A[1]	12	241
III-B[2]	32	123
III-C[2]	23	279
III-D[2]	14	466
Plasma Ascorbic Acid 1.0 or More Mg. Per Cent		
III-A[1]	6	614
III-B[2]	48	197
III-C[2]	18	273
III-D[2]	12	94
Undifferentiated Plasma Ascorbic Acid Content		
I[1]	9	189
All	237	246.300

[1] Computed as within-the-day variance among independent triplicates or quadruplicates done on the same day.
[2] Computed as ½ the variance of the difference between independent duplicates done on the same day.

Table 2. Summary of data on the error of a single galvanometer reading on a dye blank plus plasma filtrate, in log units, by dye-stock, and by ascorbic acid content of plasma.

The average level in series I, the first work with the micromethod which was done in the Study laboratory, is higher than in series II and III. Series II should represent optimum performance for the Study laboratory. The values for the four series which provide the bulk of the information on L_p lie between those for series I and II, in the main, and average 134.72×10^{-5}. If all the information of Table 3 is pooled, the average variance is 158.389×10^{-5}. Despite the evidence of heterogeneity among estimates in Table 3, this average variance is considered to be the best single estimate which the data

timates are 8.9, 10.3, 10.0, 16.3, 12.1, 11.3, 15.1, 11.9, and 15.1 for the nine levels from .10 to 2.00 per cent. The regression coefficient is 2.22, and t=1.89, which is well within the range of chance variation for 7 degrees of freedom.

Strength of Standard Ascorbic Acid Solution Mg. Per Cent	Degrees of Freedom (n)	Error Variance[1] ($S^2 \times 10^8$)	Degrees of Freedom (n)	Error Variance[1] ($S^2 \times 10^8$)
	Series I		Series II	
.10	10	124	15	51
.30	12	138	15	82
.50	12	82	15	115
.75	12	399	15	158
1.00	12	156	15	137
1.50	15	299	15	159
2.00	15	369	15	88
All	88	233.73	105	112.83
	$\chi^2=12.65$, n=6, P=.05		$\chi^2=6.95$, n=6, .30 <P <.50	
	Series III-A		Series III-B	
1.25	10	124	15	89
1.88	12	118	14	245
	F=1.05, P> .05		F=2.76, P <.05	
	Series III-C		Series III-D	
1.25	8	221	5	101
1.88	9	80	5	17
	F=2.76, P> .05		F=6.00, P <.05	

[1] Computed as within-the-day variance for replicated independent readings.

Table 3. Summary of data on error of a single galvanometer reading on a dye blank plus a standard solution of ascorbic acid, in log units, by strength of standard solution, and by dye-stock.

afford[4]. It compares with 108.775 x 10^{-8} for L_b and 246.300 x 10^{-8} for L_p.

Differences ($L_b - L_p$) and ($L_b - L_s$). From these three variances may be derived the error variances of X_2 or ($L_b - L_p$) and X_3 or ($L_b - L_s$), assuming L_b and L_s to be triplicated, and the errors in readings on L_b and L_p, and on L_b and L_s, to be independent in the statistical sense. Thus, S_2^2, the error variance of X_2, may be found

[4] High, low, and medium estimates might be used, but they would all be of the same general order of magnitude, 100 x 10^{-8} to 200 x 10^{-8}.

as $[1/3\ (108.775) + (246.300)] \times 10^{-5}$ or 282.558×10^{-5}. If L_p were duplicated, and the mean of the two independent duplicates taken as the L_p reading, the error variance of $(L_b - L_p)$ would be reduced to 159.408×10^{-5}. Similarly, the error variance S_3^2 may be found as $1/3\ (108.775 + 158.389) \times 10^{-5}$, or 89.054×10^{-5}.

In order to test the assumption that the individual errors are uncorrelated and thus the advisability of adding the separate error variances to estimate the error variance of a difference, a special study was made of the error of $(L_b - L_s)$. In each series the daily triplicate readings of L_b were paired randomly with the triplicate readings on that day for L_s for a particular standard ascorbic acid concentration, *e.g.*, one per cent, and the three independent differences $(L_b - L_s)$ were found. Thus, a series of six days furnishes eighteen $(L_b - L_s)$ differences for a given standard concentration of ascorbic acid. Their variance within days, accordingly, constitutes an estimate of the experimental error of $(L_b - L_s)$ for single readings. A series having L_s readings at six C_s levels provides six different estimates of the error variance of $(L_b - L_s)$[5]. For comparison, the within variance of L_b for that series may be added to the within variance of L_s for the particular standard concentration of ascorbic acid to yield another estimate of the error variance of $(L_b - L_s)$. The laboratory observations permit twenty-two such comparisons. In every instance the F-ratio of the two variances is insignificant and close to unity. Eleven of the estimates based on sums exceed those found directly, nine fall below, and two are identical because the within error of L_b was zero. Hence, the assumption of zero correlation between the errors of corresponding duplicates is amply supported for $(L_b - L_s)$ and may likewise be extended to the parallel $(L_b - L_p)$ difference.

Standard Concentration (C_s). The error variance of C_s, or S_1^2, may be found indirectly by the device described by Wiehl and

[5] Since, however, they all share common L_b values, they may not be considered independent estimates.

Kantorovitz (2). It will be recalled that C_s is the standard ascorbic acid concentration (in metaphosphoric acid) added to the dye-acetate blank. The standard solutions were freshly prepared each day, and it is most reasonable to regard the errors involved in their preparation as normally distributed about zero means. Since the same C_s solution was used for all experiments on a given day, any error in C_s carried through the day without affecting the variation among replicate readings. Only the variation among days is increased by the error of C_s. Wiehl and Kantorovitz suggested that the error of K, where

$$K=\frac{C_s}{L_b-L_s}=\frac{X_1}{X_3},$$

should be calculated directly both within and among days for a single dye-acetate solution and standard ascorbic acid concentration. Then, since there is no error of C_s within days, it should be possible to compute the error of K within days from estimates of the error of $(L_b - L_s)$, using formula (3) above. This equation reduces to

$$(5)\quad S^2_K = \left[\frac{\overline{X}_1}{\overline{X}_3}\right]^2 \cdot \left[\frac{S_3}{\overline{X}_3}\right]^2$$

for $r=0$, $S_1=0$.

Such estimates of the within-the-day error of K are, in fact, in close agreement with those obtained directly from the series of random $(L_b - L_s)$ differences mentioned above. Moreover, from the study of duplicate L_p readings on blood samples, many of which were done on a single day, it is clear that the experimental error of L_p readings among days is of the same order as that within days. A similar conclusion should follow for the L_b and L_s readings. Hence, it seems entirely fair to employ the within-the-day variance of $(L_b - L_s)$ as the error variance of $(L_b - L_s)$ among days, freed of

any influence which errors in C_s might have upon it if it were taken as the among-days variance.[6] Then the variance of K among days may also be written as the variance of a ratio, or

$$(6)\quad S^2_K = \left[\frac{\overline{X}_1}{\overline{X}_3}\right]^2 \cdot \left[\frac{S_1^2}{\overline{X}_1^2} + \frac{S_3^2}{\overline{X}_3^2}\right]$$

and S_1^2 may be found by substituting for all other factors and solving directly. Formula (6) is, of course, the same as formula (3) except for the omission of the third term within the brackets, which may be assumed to vanish. By this method twenty-two estimates of the error of C_s were derived for the nine different C_s levels. Because each estimate is based upon rather few degrees of freedom, the twenty-two estimates are highly variable but suggestive of a marked relationship to the C_s level. When all the information pertaining to each C_s level is combined,[7] regression analysis reveals a highly significant trend of error with increasing C_s. Figure 1 shows the nine error estimates as standard deviations and the regression line

$$Y = .03718 + .03939\ X$$

which fits the points rather well. From the regression equation, therefore, it is possible to obtain S_1^2 appropriate to the strength of any standard solution employed in the laboratory. Such estimates appear in Table 4. The relative error of 41 per cent for .10 per cent solutions may seem high, but the corresponding standard deviation of .041 is less striking and represents a degree of accuracy within the range of toleration. All these estimates are, however, well above those of 1.5 to 3 per cent reported by Wiehl and Kantorovitz for the macromethod. The increase in error is one price of the economy of plasma which the micromethod makes possible.

[6] Errors in C_s should materially affect the difference $(L_b - L_s)$ among days, and analysis shows that the variance of $(L_b - L_s)$ among days usually exceeds that within days by a significant margin.

[7] The two or four estimates at each C_s level do not differ significantly.

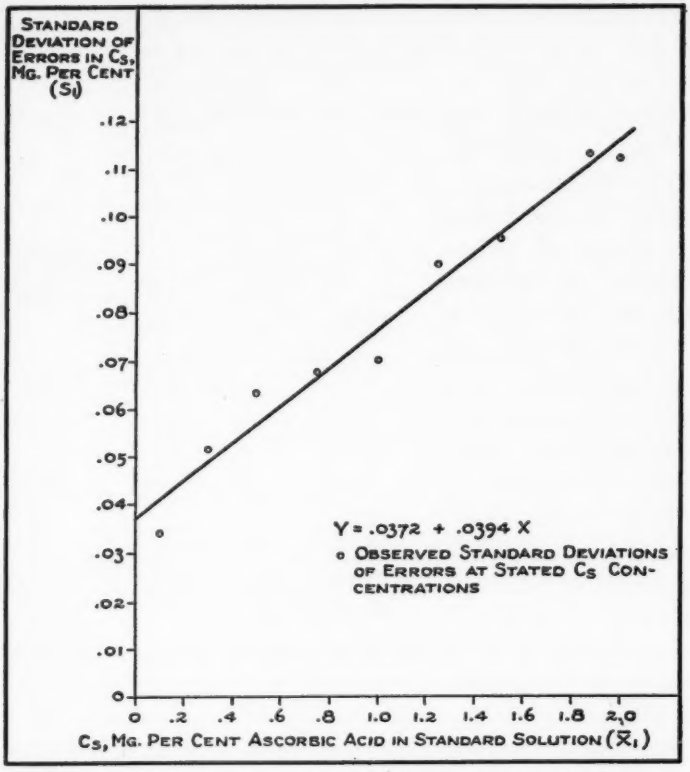

Fig. 1. Relation between error made in preparing standard ascorbic acid solutions and the concentration of ascorbic acid employed for the standard solution.

Estimates of Mean Values for C_s, $(L_b - L_a)$, and $(L_b - L_p)$

Before the three estimates of error may be utilized in formula (4) to yield the error of a determination upon a sample of plasma, the values of $\overline{X}_1$, $\overline{X}_2$, and $\overline{X}_3$ must be obtained. Evidently $\overline{X}_1$ is the standard concentration of ascorbic acid in the metaphosphoric acid solution added to the dye-acetate blank. The six series yield twenty-two estimates of $\overline{X}_3$, the mean of $(L_b - L_a)$. The average values for

each of the nine C_s levels fall along a straight line of equation

$$Y = .00087 + .0204\,X$$

where X is the C_s level (mg. per cent ascorbic acid in standard solution). Theoretical considerations suggest a regression line passing through the origin, whereas the observed line cuts the Y axis at +.00087. Such a discrepancy, of course, is entirely too small to be taken as evidence against theoretical expectation. Forced through the origin, the line would have the approximate equation $Y = .021X$. Although values of $\overline{X}_3$ calculated from such an equation could accord more nicely with theoretical expectation than those obtained from the observed regression equation, the differences between the estimates would be small. The values of $\overline{X}_3$ in Table 5, and shown in Figure 2, have been computed from the observed regression equation.

Table 4. Estimates of the error made in preparing standard ascorbic acid solutions, by strength of solution.

Concentration of Ascorbic Acid in Standard Solution Added to Dye Blank, in Mg. Per Cent	Error Variance[1] ($S^2 \times 10^3$)	Coefficient of Variation Per Cent
.10	1.690	41.1
.30	2.400	16.3
.50	3.234	11.4
.75	4.451	8.9
1.00	5.862	7.7
1.25	7.467	6.9
1.50	9.265	6.4
1.88	12.371	5.9
2.00	13.445	5.8

[1] Estimated from the regression equation $Y = .03718 + .03939\,X$, where X is the concentration of ascorbic acid in standard solution added to the dye blank, and Y is the standard deviation of the errors of C_s.

The laboratory observations provide no direct means of estimating $\overline{X}_2$, the mean $(L_b - L_p)$, for a given concentration of ascorbic acid in the plasma, since the "true" content of any sample is, of course, unknown. However, the relationship between C_p and $(L_b - L_p)$ is theoretically the same as that between C_s and $(L_b - L_s)$, and the same regression equation should be applicable to both systems. Although it may involve some systematic error, especially in the region below .5 mg. per cent ascorbic acid, the observed regres-

Estimates for C_s the Strength of the Prepared Ascorbic Acid Solutions in Mg. Per Cent		Estimates for $(L_b - L_s)$ at Each C_s Level	
$\overline{X}_1$	$S_1^2 \times 10^3$	$\overline{X}_3$	$S_3^2 \times 10^3$
.10	1.690	.0029	89.054
.30	2.400	.0070	89.054
.50	3.234	.0111	89.054
.75	4.451	.0162	89.054
1.00	5.862	.0213	89.054
1.25	7.467	.0264	89.054
1.50	9.265	.0315	89.054
1.88	11.371	.0392	89.054
2.00	13.445	.0417	89.054

Estimates for $(L_b - L_p)$ at All C_s Levels, According to C_p Level Stated as Mg. Per Cent and Number of L_p Readings Made

C_p	$\overline{X}_2$	Error Variance $S_2^2 \times 10^3$ by Number of Readings		
		One L_p	Duplicate L_p	Triplicate L_p
.10	.0029	282.558	159.408	118.358
.25	.0060	282.558	159.408	118.358
.50	.0111	282.558	159.408	118.358
.75	.0162	282.558	159.408	118.358
1.25	.0264	282.558	159.408	118.358
2.00	.0417	282.558	159.408	118.358

Table 5. Summary of estimates of means and standard deviations required for computation of the error of a determination of the ascorbic acid content of plasma.

sion equation was employed in computing the values of $\dot{\overline{X}}_2$ in Table 5.

Experimental Error of Estimated Ascorbic Acid Content of Plasma

The estimates derived thus far may be put together by means of formula (4) which substitutes the formula for the variance of a product $(Z = X_1 \cdot X_2)$ in the formula for the variance of a ratio (Z/X_3) on the assumption, justified above, that the errors of X_1 and X_2 are uncorrelated. The correlation coefficient in formula (4) pertains to Z and X_3, and is of unknown magnitude. It is not worth

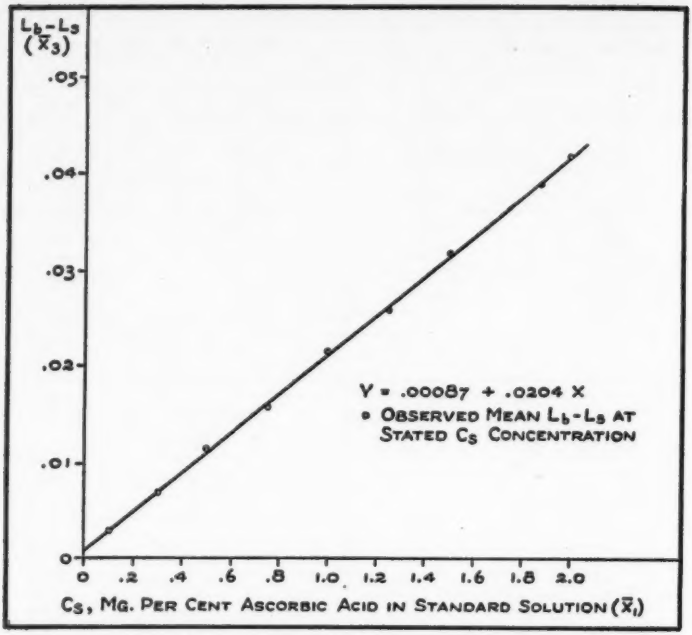

Fig. 2. Relation between difference in log readings on dye-blank and on dye-blank plus standard solution and the ascorbic acid content of the standard solution.

the labor of estimation, however, for it can be shown that, no matter what value r may take within its possible range from −1 to +1, the term in which it appears must be negligible in size. Then it is an easy matter to compute the variance of an estimate of the ascorbic acid content of a sample of plasma by means of the shortened formula

$$(7)\quad S_t^2 = \left[\frac{\bar{X}_1 \cdot \bar{X}_2}{\bar{X}_3}\right]^2 \cdot \left[\frac{S_1^2}{\bar{X}_1^2} + \frac{S_2^2}{\bar{X}_2^2} + \frac{S_3^2}{\bar{X}_3^2} + \frac{S_1^2 S_2^2}{\bar{X}_1^2 \bar{X}_2^2}\right]$$

Estimates of S_t for the 9 C_s levels and for 6 ascorbic acid levels are given in Table 6. Figure 3 gives a plot of these estimated standard

Strength of Standard Solution Per Cent	Error of Determination According to Amount of Ascorbic Acid Found in Plasma					
	.10	.25	.50	.75	1.25	2.00
.10	.082	.125	.210	.299	.481	.756
.30	.078	.091	.124	.164	.250	.385
.50	.078	.085	.104	.128	.185	.277
.75	.079	.083	.095	.112	.152	.220
1.00	.080	.083	.091	.104	.135	.190
1.25	.080	.083	.090	.100	.126	.173
1.50	.081	.083	.088	.097	.120	.162
1.88	.081	.083	.088	.095	.114	.151
2.00	.081	.083	.087	.094	.113	.148

Table 6. Estimates of the error of single determinations of plasma ascorbic acid, according to strength of standard solution and the estimated ascorbic content of plasma.

deviations and permits one to read off the estimated standard deviation appropriate to any C_s and C_p within the range .10 to 2.0 mg. per cent.

The error curve for any C_s concentration above .10 per cent rises only slowly with increasing C_p, and declines fairly rapidly as C_s is increased. Evidently the accuracy obtainable with prepared dye solutions containing as little as .10 per cent ascorbic acid is not high, entirely apart from any question of systematic bias. The use of standard solutions containing one or more per cent ascorbic acid is clearly indicated. The lowest line in Figure 3 gives the curve of error reported by Wiehl and Kantorovitz for C_p determinations obtained by means of the macromethod described by Mindlin and Butler. A significant disparity exists between this curve and the lowest curve of error for the micromethod. For maximum accuracy, therefore, the macromethod seems indicated if the available quantities of plasma are sufficiently large. The reliability of the micromethod seems rather high in the light of the fact that it requires about 1/20th of the amount of plasma needed for the macromethod. When it is imperative to economize on blood, therefore, the micromethod may be utilized with only slight sacrifice of accuracy.

The practical utility of these results stems from the ready way

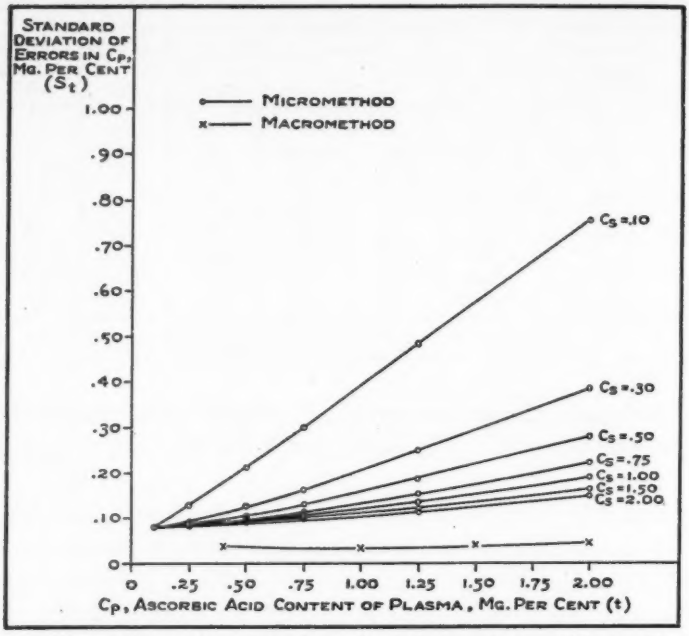

Fig. 3. Estimates of experimental error for single determinations of the ascorbic acid content of plasma by micromethod, for different standard concentrations, with comparative estimates for the macromethod.

in which errors may be read from the curves of Figure 3. Other biochemical laboratories may operate with more or less efficiency than the Study laboratory upon the work of which this report is based, but the differences might not be large. Assuming a laboratory routine of comparable efficiency, and employing triplicate L_b and L_s readings, the error of any ascorbic acid determination may be read directly from the appropriate curve in Figure 3. If the standard solution should contain 2.0 mg. per cent ascorbic acid, for example, the curve for C_s equal to 2.0 per cent would be the appropriate error curve to consult. A plasma determination of, say, .60 mg. per cent of ascorbic acid could then be placed within its 95 per cent confidence limits ($t \pm 1.96\ S_t$) of .60 ± .18, or .42 to

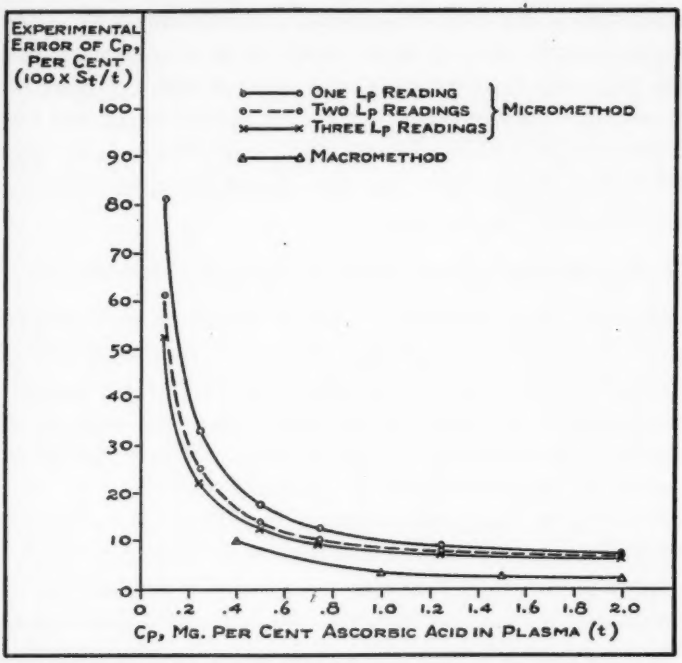

Fig. 4. Effect of duplication and triplication of galvanometer reading on dye-blank plus plasma filtrate in reducing the experimental error of C_p, in percentage terms.

.78. For a plasma determination of 2.0 mg. per cent the limits would be 2.0 ± .29, or 1.71 to 2.29 mg. per cent.

The reliability of micro determinations can, of course, be somewhat increased by independent replication of the L_p reading. Since the micromethod requires such small quantities of plasma, replication demands only a small additional amount. Figure 4 shows the extent to which the error curve for C_s equal to 2.0 mg. per cent may be reduced by duplication and by triplication of the L_p reading, and also permits comparison with the error of the macromethod using one L_p reading. The standard deviations are presented in relative form in this figure, in contrast to Figure 3, as

percentages of the estimated ascorbic acid contents of the blood samples, in order to bring out the rapid change in relative accuracy with increasing C_p. Even triplication does not suffice to bring the micromethod curve down to that for the macromethod, and triplication has little advantage over duplication. It also seems clear that replication has little effect upon the relative error of an estimated C_p above 1.25 per cent.

Systematic Error From Choice of Standard Concentration

The foregoing statistical analysis is concerned with *random* errors of measurement and does not touch upon the question of *systematic* or biased errors. It is, in fact, quite possible that the micro determinations are subject to appreciable bias. One point in the preceding discussion gives a clue to a minor bias to which the method was subject in the Study laboratory.

In the course of estimating mean values of $(L_b - L_s)$ for different standard concentrations (C_s), it was noted that the regression line failed to pass through the origin as required by the theory of the transmission of monochromatic light through a homogeneous solution. Although the departure from expectation is too small to affect the estimates of *random* error, it is sufficient to introduce some *systematic* error, especially if low standard concentrations are employed in the derivation of K. The observed regression line yields the following set of K values for the standard concentrations (C_s) .1, .3, .5, .75, 1.0, 1.25, 1.5, and 2.0 mg. per cent: 34.5, 42.9, 45.0, 46.3, 46.9, 47.3, 47.6, and 48.0. Since K is employed as a multiplier of $(L_b - L_p)$ or the log of the ratio of galvanometer readings on dye blank plus plasma and on dye blank alone, clearly the estimated ascorbic acid content of the plasma depends upon the choice of standard concentration.

By assuming fixed values for $(L_b - L_p)$ for particular "true" C_p values, it is possible to compute the estimates which would follow from the use of several different standard concentrations. Such

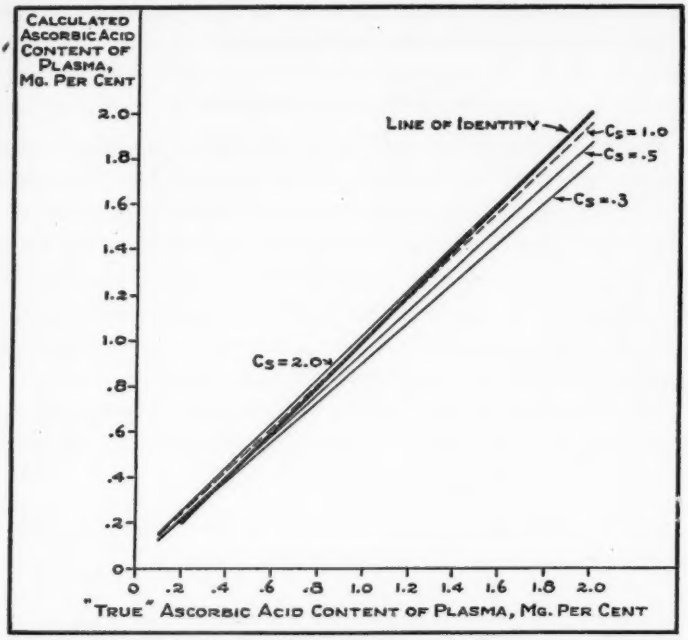

Fig. 5. Systematic errors in estimated ascorbic acid content of plasma arising from choice of standard concentration.

estimates have been plotted in Figure 5, the ordinate being the calculated value of C_p, and the abcissa its "true" value. The heavy line there represents the region of accurate estimation. The lighter lines for several different standard concentrations tend to approach this line as C_s is increased to 2.0 mg. per cent. They also cross the heavy line at the points where $C_s = C_p$. There is no bias from this source if the standard concentration is identical with the estimate for the plasma filtrate sample. The use of standard concentrations below 1.0 mg. per cent involves considerable error in the region above 1.0 mg. per cent, but such low standard concentrations are not generally considered for routine work. For standard concentrations between 1.0 and 2.0 mg. per cent this particular type of error is

negligible, although it involves errors of .03 to .04 in the region below .5 mg. per cent ascorbic acid in plasma.

The Turbidity Correction

One possible source of error in photelometric determinations of ascorbic acid is the presence, in solutions introduced into the colorimeter, of particles which reduce the transmission of light. The turbidity correction is advocated (5, 6) to compensate for this error, which operates by depressing galvanometer readings, especially on test solutions. An imperceptible degree of turbidity may lower a galvanometer reading enough to make a marked reduction in the estimated ascorbic acid content of the plasma filtrate.

The procedure followed in the Study laboratory is based upon that given by Butler and Cushman (6). In lieu of their expression

$$C = K (\log G_s - \log G_b + \log 100 - \log G_{t_s}),$$

where G_{t_s} is the galvanometer reading on the completely decolorized test solution, the Study laboratory employed

$$C = K (\log G_s - \log G_b + \log G_{t_b} - \log G_{t_s})$$

where G_{t_b} is the galvanometer reading on the decolorized dye blank. Since either G_t reading should be 100 in the absence of any turbidity, and only the test solution (containing plasma) is subject to appreciable turbidity, the difference between the two procedures is minor. Most G_{t_b} readings were either 100 or very close to it. However, the inclusion of both turbidity readings does introduce the possibility of a *reduction* in the final estimate of C, whereas correction for turbidity in the test solution only must lead to an *increase* in C if $G_{t_s} < 100$. A reduction could arise only if $G_{t_s} > G_{t_b}$, or when, in other words, the dye blank was more turbid than the test solution. The preparation of the solutions makes this very unlikely. Hence, the presence of negative corrections in C should index the experimental error implicit in the turbidity correction.

If it were found that the turbidity corrections in C values con-

centrate about 0 with relatively little scatter, it would follow that the solutions employed were clear enough to permit accurate determinations by the Mindlin and Butler method. On the other hand, large positive deviations from 0 would reveal the presence of particles interfering with light transmission. Turbidity of this degree might be introduced occasionally into the mixture of dye blank plus plasma filtrate because of insufficient or improper centrifuging. It is instructive, therefore, to study the corrections actually made in the Study laboratory. Parenthetically it may be noted that the correction does not alter the order of magnitude of the final estimates of experimental error presented above in Table 6 and in Figure 3.

The turbidity correction was performed for 222 different blood samples in series III-B, C, and D. In 82, or 36.9 per cent of the cases, the correction was zero. A complete distribution of the changes appears in Table 7 in both relative and absolute form, and separately for parts B, C, and D of series III. Large changes are

Table 7. Distributions of turbidity corrections made in several series of micro determinations of the ascorbic acid content of plasma.

Turbidity Correction Mg. Per Cent Ascorbic Acid	Series						Total	
	B		C		D			
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
−.150 to −.101			1	1.3			1	.5
−.100 " −.051	7	7.7	9	12.0	11	19.6	27	12.2
−.050 " −.001	10	11.0	22	29.3	10	17.9	42	18.9
0 " +.049	50	54.9	29	38.7	19	33.9	98	44.1
+.050 " +.099	8	8.8	7	9.3	5	8.9	20	9.0
+.100 " +.149	5	5.5	5	6.7	8	14.3	18	8.1
+.150 " +.199	4	4.4	1	1.3	2	3.6	7	3.2
+.200 " +.249	5	5.5	1	1.3			6	2.7
+.250 " +.299								
+.300 " +.349	1	1.1					1	.5
+.350 " +.399								
+.400 " +.449								
+.450 " +.499	1	1.1					1	.5
+.500 " +.549					1	1.8	1	.5
Total	91	100.0	75	99.9	56	100.0	222	100.2

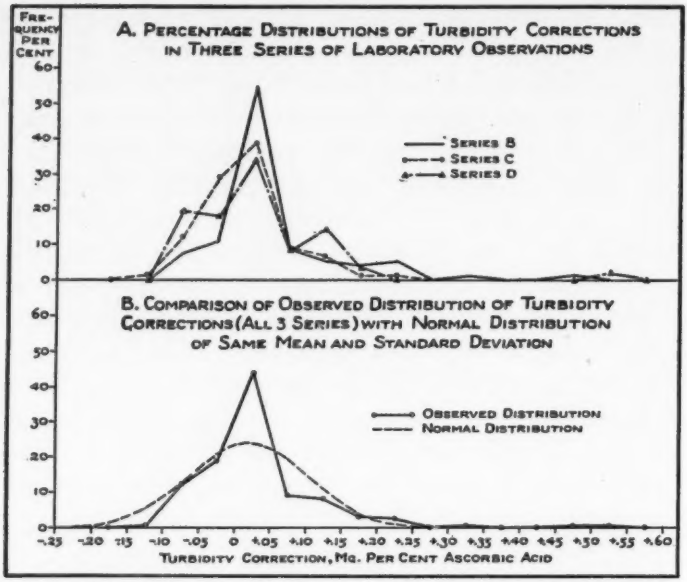

Fig. 6. Distributions of turbidity corrections made in estimates of ascorbic acid content of plasma samples.

clearly infrequent, 44.1 per cent lying between 0 and +.049, 72.0 per cent between −.050 and +.099, and 92.3 per cent between −.100 and +.149 mg. per cent ascorbic acid. The three changes of some magnitude are +.315, +.459, and +.530. The mean is +.0198.

Refined statistical treatment is somewhat hampered by the fact that, in any series, the corrections made on a given day are not completely independent, since the same dye-acetate solution was used, and a single turbidity factor for the dye blank was also employed. However, the various statistical tests which may be readily applied, such as the F test of means, the likelihood ratio test of variances, and the contingency-table test for independence, all unite in suggesting that the three parts of series III differ by a wider margin than chance would be expected to produce. Furthermore, within each part there is significant heterogeneity from day to day, al-

though the corrections themselves are independent of the uncorrected C_p values. The correlation coefficients between the corrections and the uncorrected C values are −.11, +.08, and −.08 for parts B, C, and D, respectively. Each distribution of corrections departs very significantly from the normal probability distribution, being too peaked and skewed in the direction of higher + changes. Figure 6 contains a plot of each distribution and also a comparison of the total distribution with a normal distribution having the observed mean and variance. The following hypothesis may be ventured in explanation of the distribution of corrections: to a chance distribution of zero mean there is added a fairly small set of + changes belonging to a different system; this set represents the determinations on plasma samples having some turbidity, and only for them does the correction assume any real importance. The fact that 30 per cent of the turbidity corrections are reductions indicates that the method of adjusting for turbidity is subject to some experimental error. However, this error is rather small, since only one among more than 100 exceeds .1 mg. per cent ascorbic acid.

Summary

Laboratory observations from the Medical Evaluation of Nutritional Status Study provide a means of estimating the experimental error of single determinations of plasma ascorbic acid by the micromethod of Mindlin and Butler. The sources of error are analyzed and estimates of each component made on the basis of independent duplicate or replicate readings. The experimental error is shown to depend not only upon the amount of ascorbic acid judged to be present in the plasma, but also upon the strength of the known concentration of ascorbic acid employed for comparison. The resulting standard deviations of error are shown graphically and contrasted with the lower estimates of Wiehl and Kantorovitz for the macromethod. With standard (known) concentrations of 1.0 to 2.0 mg. per cent ascorbic acid, the standard deviations are of the

order of .08 to .20 mg. per cent if the galvanometer readings on dye blank and on dye blank plus standard solution are triplicated. Duplication or triplication of the galvanometer reading on dye blank plus plasma filtrate fails to lower the experimental error by appreciable margins.

The errors of .08 to .20 mg. per cent ascorbic acid compare with errors of about .04 mg. per cent estimated for the macromethod. The sacrifice of accuracy which the micromethod entails, therefore, is slight in view of its economical blood requirements, and apart from the question of *systematic* bias.

Some systematic error is involved in the choice of standard concentrations. However, the use of high standard concentrations (*e.g.*, 1.0 to 2.0 mg. per cent) leads to far less error in the region of low plasma values than does the use of low standard concentrations for the region of high plasma values. Both systematic and random (experimental) error, therefore, are minimized if standard concentrations of 1.0 or more mg. per cent are employed.

Routine turbidity corrections made for more than 200 plasma determinations indicate that only infrequently does this refinement sensibly disturb the estimated ascorbic acid content of plasma samples. In a few instances, however, the corrections were appreciable.

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ANNOTATIONS

SOLVING SCHOOL HEALTH PROBLEMS[1]

Out of a four-year intensive school health study sponsored by the Department of Health and the Board of Education of New York City has come more than an interesting and stimulating report. This volume presents a lively account of the practical application of past and current studies and experiences to the New York school system through joint planning and cooperative action under dynamic leadership.

Outcomes were doubtless influenced by the sponsors' faith, as ex-expressed in the Foreword, that school health service is a vital protective agent in a democratic society and that its procedures can and must be improved, combined with the staffs' objective—the effective utilization of organized effort for the better health of school children. The volume is dedicated "To that large group of cooperative people—teachers, principals, physicians, nurses, dentists, dental hygienists, educational and health administrators—who helped, by work, thought, and criticism, by reading, writing, conferring, suffering inconvenience and interruption, and approving changes, to review and reconstruct and modernize a vast service established to protect and promote the health of school children." The study was (a) supported jointly by the Liquidating Committee of the American Child Health Association, the Metropolitan Life Insurance Company, the Milbank Memorial Fund, and by Social Security funds from the Children's Bureau allocated by the State Department of Health, and (b) conducted under the auspices of an advisory committee of representatives of the sponsors, the Department of Health and the Board of Education of the City of New York, while the printing was handled in the effective manner characteristic of the Division of Publications of the Commonwealth Fund.

[1] Nyswander, Dorothy B.: Solving School Health Problems. The Astoria Demonstration Study. The Commonwealth Fund, 1942, 377 pp.

In approaching the problems within the school health service, consideration was given to the children and their families, to the administrative structure of the two city departments immediately concerned, and to the functioning of the service. Searching questions were raised: Have the school medical and nursing staffs translated their guidance into such simple terms that in spite of ignorance, language difficulties, and substandard incomes, these families have understood what the child's health problems are and how and where they can get aid? How much of the running around from clinic to private physicians and back to clinic again lies at the door of the school health service? How well has the community appreciated the fact that so large a proportion of its population is going to have difficulty in paying for private medical care when the children in the family need such care? Here, as elsewhere, were found: lack of provisions for joint planning, overgrown pathways for developing new methods, some wasteful procedures because they duplicated the work of others or because they were tasks that did not need doing at all, sometimes associated with a lack of good records.

In its plan of work the study passed through three phases. Following analyses of difficulties of the school health program, came the stage of experimentation with methods of solving the difficulties, and later the period when its field laboratory became the teaching center for school health work. Procedures found workable in Astoria were tried out in other areas of the City—a step necessary to check on whether these techniques would stand the test of survival at the hands of people who had not been through the intensive working experience of the experimental district.

Much has been written concerning health examinations. "With the parent present at the examination, with stress on adequate history taking, with emphasis on the interpretation of his findings to parent, nurse, and teacher, and careful attention to planning after-care of the child, the school physician is now meeting his educational opportunities and responsibilities. His data are adequate, for he has not neglected those facts coming from the teacher and the home which relate to the educational, emotional, and social problems of the child. His attitude toward his work is more confident because he has a clearer understanding of his function in relation to the school and the community. His professional morale is strengthened because he is giving his best judgment in a variety of ways each day."

Is it better to select children for medical and nursing attention by grades or by special referral from nurse-teacher conferences? The study shows that the proportion of children who secured correction or were under treatment was larger for the specially referred group; and that a larger proportion of children in the specially referred group were selected for follow-up by the nurses, either because of the urgency of the condition or because of the indifference of the parent, and a larger proportion of the specially referred group that was followed up had professional attention whether or not the parent was present at the examination. Regardless of whether the children were in the first grade or were specially referred, those whose parents were present at the examination required less follow-up by the nurse than those whose parents were not present.

In exploring possibilities for teacher participation a Pupil Health Card was developed and a new type of teacher-nurse conference was introduced which made the teacher the starting point of the health service. Constructive recommendations are offered to teachers, physicians, and nurses which emphasize attitudes rather than procedures as important in securing a coordinated program. Consultation by the nurse in school with the parent became an important feature; incidentally a note signed by the principal was found more productive than one signed by the nurse. The value of the type of conference evolved by the study is indicated in the results obtained in the vision program where the nurses reduced the cases they were carrying from 10 to 3 per cent of the school registration within a school year. At the same time, even recognizing that the nurse has between ten and twenty-five different types of tasks to do each day, some answers were found to the question, "What plans does the nurse need to make for the day's work ahead?" Furthermore, the real criterion for choosing the home visit in preference to the school conference as a means of working out with the parent a course of action to be taken may be the answer to the question: "Will a home visit to this particular family be of more aid in understanding the family's problems and securing care for this child than a conference with the parent in school?"

Procedures for testing visual acuity and conducting follow-up work were modified, and coordinated work made it possible to secure 80 per cent corrected vision cases, an improvement of 30 per cent. Teachers and the ophthalmologist agreed in their testing of all children not wearing glasses in ninety-six cases out of a hundred, "and since 2 out of 3 cases

in which they disagree are in the direction of referring cases rather than in failing to refer them, it is basically sound as a practical administrative procedure to use the Snellen test scores obtained by teachers in the first screening of visual acuity defect cases." Of available methods the audiometer test was considered the most satisfactory screening device for selecting children with loss of hearing. Administering the 4 A test two or three times to children showing loss of hearing on the first test would probably prove to be a sufficiently reliable screening device for referring children directly to diagnostic and treatment services.

In obtaining dental care, experience indicated the need for education in the values of dental service in order to secure earlier detection of caries and treatment. "It is now out of keeping with sound theory in health education to emphasize one program to the exclusion of other efforts to provide for the child's welfare. The child cannot be helped to assume responsibility for his health through campaigns carried out by specialists. Sound attitudes can be developed only through unified teaching and through one source of instruction,—the teacher. The dental hygienist should work with the teacher, not with the children."

Improvement in the care of the cardiac child included: standardization of the diagnostic nomenclature; establishment of diagnostic services for the school physician and, on request, for the private physician; stressing regular medical supervision of known cardiac children; and placement of more emphasis on explanation, interpretation, and guidance as the best method of improving the understanding and care of the cardiac child in school.

Much attention was devoted during the course of the study to the place of the private physician and to interrelationships, to staff education for which ingenious means were devised, to the development of parent responsibility, to policies, and to records. Many valuable records and appraisal forms are reproduced, together with statistical tabulations and other extensive data of practical value to anyone concerned with a school health program. One must read the book to appreciate its unusual merits.

This study is an example of the usefulness of private foundations and private agencies to governmental agencies in making it possible for the latter to appraise their activities and to plan constructively for future developments.

IRA V. HISCOCK

HOSPITAL DISCHARGE STUDY[1]

STUDIES of hospital morbidity usually suffer from the lack of a population base to which to relate the excellent records of illness. This study met this problem by obtaining for one year records of discharges from practically all hospitals in New York City and relating the illness records to the population census of the City. The more than half million cases were carefully allocated to the residence of the patient so that hospital rates could be computed for health center districts and for residents of New York City, excluding nonresidents who were hospitalized within the City.

The annual rate of hospital discharges among residents of New York City was 70 per 1,000, ranging in the five boroughs from 54 for Queens to 99 for Manhattan, and in the thirty-one health center districts from 40 per 1,000 in Maspeth-Forest Hills to 127 in the Lower East Side. The discharge rates in the thirty-one health center districts showed a rather close correlation with death rates. Data are shown in broad age groups for each of the thirty-one health center districts.

Tabulations in seven age groups show variation in annual hospital discharges from 64 per 1,000 at 5-14 years to 96 at 65 years and over. For all ages the annual hospital discharge rate was 64 per 1,000 males as compared with 77 per 1,000 females.

Data are shown in various tables for some fifty to sixty diagnosis groups, including discharge rates by sex for all ages and by age for both sexes. Obstetrical conditions lead with 74,095 discharges followed by tonsils and adenoids (including tonsillectomy) with 65,797 discharges. Other important diagnoses were neoplasms, cardiac diseases, appendicitis, and fractures. Data are also given on the percentage of hospital cases that ended fatally, by age and duration of hospital stay, and by diagnosis. The small volume is literally filled with interesting facts about hospital care and related items.

The present book on general aspects and local distribution of hospitalization is published as the first of three volumes; the second will deal with a detailed analysis of hospitalization of important diseases, and the third will outline a system for the routine reporting of hospital cases. In

[1] Deardorff, Neva R. and Frankel, Marta: HOSPITAL DISCHARGE STUDY: An Analysis of 576,623 Patients Discharged from Hospitals in New York City in 1933. New York, The Welfare Council of New York City, 1942.

fact the main objective of the whole study seems to have been the formulation of this plan for current reporting of cases with the great mass of interesting morbidity data coming as a sort of byproduct of that study.

SELWYN D. COLLINS

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TO TITLES OF ARTICLES AND AUTHORS IN THE MILBANK MEMORIAL FUND QUARTERLY

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